THE EFFECT OF KEYBOARD DESIGN ON PRODUCTIVITY AMONG EXPERIENCED TYPISTS

A Research Project Presented to the Faculty of the

Department of Physical Therapy of Springfield College

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Physical Therapy

By

Elizabeth L. Hangasky

Andrew M. Ives

Melissa J. Walsh

May 2007

THE EFFECT OF KEYBOAD DESIGN ON PRODUCTIVITY AMONG EXPERIENCED TYPISTS

A Research Project Presented
By
Elizabeth L. Hangasky
Andrew M. Ives
Melissa J. Walsh

Approved as to style and content by:

David J. Miller, PT, PhD

Thomas P. Bianco MSPT

Thomas P. Bianco, MSPT

David J. Miller, PT, PhD
Department Chairperson

THE EFFECTS ON KEYBOARD DESIGN AMONG EXPERIENCED TYPISTS.

Walsh MJ, Hangasky EL, Ives AM. Department of Physical Therapy, Springfield College, Springfield, MA.

PURPOSE/HYPOTHESIS: The purpose of the study was to determine if experienced typists would be able to reach baseline measures of productivity and accuracy when changing from a standard keyboard to an alternative keyboard. We hypothesized that the typists will return to baseline measures of productivity and accuracy when typing on an alternative keyboard during the initial 60 minute time period.

MATERIALS/METHODS: Thirteen experienced typists, who were employees of Springfield College, ranging from the ages of 27 to 61 volunteered to participate in this study. Inclusion criteria included: (1) female; (2) 10 finger typists; (3) type at least 2 hours a day for 5 days out of the week; (4) type primarily on a standard keyboard; and, (5) speak English as their primary language. Exclusion criteria included: (1) a diagnosis of a current musculoskeletal injuries related to typing; and, (2) prior experience typing on an alterative keyboard. Three variables were tested for each subject: (1) gross words per minute, (2) net words per minute, and (3) accuracy. Three baseline measurements were recorded on the standard keyboard at 5 minute intervals. Typists then typed for 65 minutes on an alternative keyboard. At 5 minute intervals, gross and net words per minute (wpm), as well as accuracy were recorded. A questionnaire of preference was given to each participant following data collection. Three paired *t*-tests were conducted comparing baseline results on the standard and alternative keyboard, for net and gross wpm, and accuracy. Three paired *t*-tests were conducted comparing baseline results on the standard keyboard to the peak wpm (net and gross) and accuracy on the alternative keyboard. Multiple paired t-tests, using a Bonferroni Correction, were conducted to

compare the differences amongst the 5 minute intervals. An alpha level of .05 was used to test for significance in each analysis. An Interclass Correlation was conducted to determine reliability between the 3 baseline measurements on the standard keyboard. **RESULTS**: None of the subjects reached their original wpm (gross and net) after typing on the alternative keyboard for 65 minutes. There was a significant difference between baseline to baseline for gross wpm (t_{12}=7.846, p=.000) and net wpm (t_{12}=7.255, p=.000). There was no significant difference between baseline to peak gross wpm (t_{12}=4.815, p=.000) and net wpm (t_{12}=4.622, p=.001). Original accuracy was reached within 40 ± 21.21 minutes of typing on the alternative keyboard. No significant difference was found between baseline accuracy and peak accuracy (t_{12}=1.999, p=.069). Two post-hoc study power analyses indicated a very low risk of committing Type II error. The power for both tests was 0.9. **CONCLUSIONS:** Clinicians should determine the time interval in which typists will return to their original wpm when using an alternative keyboard. Baseline accuracy can be reached within 40 ± 21.21 minutes of typing on an alternative keyboard. **CLINCIAL REVELANCE**: Although original wpm was not reached by typists, the authors of this study endorse the use of alternative keyboards to help prevent the prevalence of Work Related Musculoskeletal Disorders (WRMDs).

INTRODUCTION

Use of a standard keyboard often leads to the development of musculoskeletal injuries. A majority of these injuries occur at the wrist.[1] Ergonomic specialists have designed and produced alternative keyboards for the potential to decrease the prevalence of these injuries. However it is not clear whether or not typists are capable of maintaining the same level of productivity and accuracy when switching from a standard keyboard to an alternative keyboard.

According to the Bureau of Labor Statistics in 2004, there were 92,576 repetitive trauma cases reported associated with typing or data entry. Fifty-five percent of these injuries affected the wrist, 7 percent affected the shoulder, and 6 percent affected the back.[1] These injuries result in high costs associated in temporary time absent from work, ergonomic changes to reduce the recurrence and health care expense, and rehabilitation costs.[2] Other costs are associated with decreased productivity when training people to replace injured employees. The high prevalence of injures and related costs may indicate a need to encourage typists to convert or transition to the use of alternative keyboards.

Statement of Problem

There are many repetitive work related musculoskeletal injuries associated with typing. These injuries often require rehabilitation or surgery. The use of alternative keyboard designs that incorporate a split-angle has been shown to reduce carpal tunnel pressure, and strain on the tendons and ligaments of the wrists.[15] Even though there are alternative keyboard designs used to decrease prevalence of work related musculoskeletal disorders (WRMD), there is a resistance from typists to change to the alternative keyboards, based on perceived loss of productivity and accuracy.

Theoretical and Empirical Rationale

Typists are at risk for developing complications and injuries at the wrist. These risks are due to positions and motions that occur while typing on a standard keyboard. Typing on a standard keyboard forces the hands and wrists into a non-neutral position, which can lead to repetitive stress injuries.[3] One of the most common repetitive stress injuries of the wrist associated with typing is Carpal Tunnel Syndrome.[1] Carpal Tunnel Syndrome places pressure on the median nerve. This pressure results in pain, tingling, and numbness of the wrist and fingers and can impair typing performance.[4]

Ergonomic specialists have developed alternative forms of keyboards because of WRMDs, such as Carpal Tunnel Syndrome. The alternative forms include split-angled, tilt-angled, and sloped-angled. A keyboard with a split-angle is designed to decrease ulnar deviation at the wrist. A tilt angle component to a keyboard is designed to reduce forearm pronation. Extension of the wrist is lessened by decreasing the slope or creating a negative slope of the keyboard.[5] Research has been conducted to analyze the potential benefits of alternative keyboard designs, findings include decreased prevalence of musculoskeletal injuries at the wrist, decreased angle of wrist extension and ulnar deviation, and decreased stress on the tendons and ligaments of the wrist.[5]

Even though alternative keyboards are known to decrease WRMDs, are the benefits diminished by reduced productivity and accuracy? Researchers investigating this issue have found conflicting results. Marklin, Simoneau, and Monroe,[6] documented that 20 hours of practice on an alternative keyboard was an adequate amount of time to return to baseline performance measurements. In a study by Smith[7], it took at least 2 hours of practice to be proficient on the alternative keyboard. In contrast, a study conducted by

Swanson et al found experienced typists required 5 hours of practice to obtain steady typing performance on an alternative keyboard.[8] In yet another study, researchers found it took as little as 6 minutes for experienced typists to become accustomed to the alternative keyboard slope angles and height.[9]

There are many different methods available to analyze and record typing productivity and accuracy. The KBlog,* for instance, measures typing motion, typing frequency, and how long a particular key was held.[10] Video recording can be used to record accuracy and productivity and can be used to analyze the correlation between posture and productivity.[11] The Typing Tutor 6.0† allows a typist to become familiar with the new keyboard through typing drills. This software records typing speed, total number of characters typed, and accuracy.[6]

Summary

Typing on a standard keyboard places a typist at risk for developing a WRMD. Alternative keyboards are designed to reduce or eliminate this risk. Alternative keyboards can position the wrist in a more neutral alignment, thus reducing the stress place on the tendons, and ligaments, and the nerves of the wrist region. Even though there are benefits from changing to an alternative keyboard many people are still hesitant to do so. This study will focus on if and when participants reach the same accuracy and productivity after changing from a standard to an alternative keyboard.

*Visual Basic Microsoft 2000
†Kriya Systems, Inc., Sterling, VA.

METHODS

The purpose of this study was to determine whether typists were able to reach baseline measures of productivity and accuracy when changing from a standard keyboard to a split-angled keyboard. We hypothesized that the typists would return to baseline measures of productivity and accuracy when typing on an alternative keyboard during a 65 minute time period. Methods and procedures discussed in this section were used to assess and quantify typist's ability to adapt to an alternate style of keyboards. Topics include the sampling process, instrumentation, procedures used to collect data, and data analysis procedures. The study was reviewed and approved by the Springfield College Institutional Review Board prior to data collection.

Subjects

Typists who have used only a standard keyboard and type at least 2 hours a day for 5 days in a week were the target population for this study. The accessible population for this study was Springfield College Staff Associates and other Springfield College employees. Convenience sampling was used to gather participants for this study. The participants were recruited through email, as well as, personal recruitment. The participants were asked to volunteer to participate in the study. The inclusion criteria for the participants were: (1) female; (2) 10 finger typists; (3) type at least 2 hours a day for 5 days out of the week; (4) type primarily on a standard keyboard; and, (5) speak English as their primary language. The exclusion criteria for the participants were: (1) any current musculoskeletal injuries related to typing; and, (2) prior experience typing on an alterative keyboard.

Workplace Configuration

Data were collected in a quite lab setting on a workplace terminal, ergonomically adjusted for each participant. The ergonomic adjustment of the work station consisted of adjusting the desk, chair, and monitor height. The equipment used in this study included: an ergonomic adjustable chair (HAG CREDO 3300*), Dell computer, Dell 15 inch flat screen monitor, a Dell standard keyboard, and a Microsoft® Natural Multimedia Keyboard. Ergonomic configuration of the workplace terminal was used to control for postural variables between participants, such as body alignment and mechanics using the following guidelines. The ergonomic set up of the chair included the shoulder positioned at 15 to 20 degrees of abduction and 25 degrees of flexion. The chair was adjusted to allow the hip and knees to be at 90 degrees of flexion, with the subject's feet firmly on the floor. The front edge of the seat of the chair was approximately 2.5 centimeters away from the back of the knees. The backrest of the chair was adjusted to support the lumbar spine, at approximately the level of the fifth lumbar vertebrae.[12] The desk was adjusted to allow the proper positioning of the hands and arms while typing; the hands were positioned in neural extension/flexion, supination/pronation, and ulnar/radial deviation. The monitor was adjusted to allow the participant's eye level to be even with the top of the monitor.

Alternative Keyboards

The alternative keyboard in this study was the Microsoft® Natural Multimedia Keyboard†. The alternative keyboard has a 12 degree split-angle, a 7 degree reverse

*HAG Inc. 108 Landmark Dr, Greensborrow, NC 27409
†Microsoft Corporation. 1 Microsoft Way, Redmond, WA 98052

slope-angle and a 14 degree tilt-angle. The slant angle determines the amount of ulnar and radial deviation allowed by the keyboard. The slope angle determines the amount of flexion and extension allowed by the keyboard. The tilt angle determines the amount of supination and pronation of the wrist.[5] The spacing of the keys on the alternative keyboard was equivalent to the key spacing on the standard keyboard.

Speed Typing Test 2000

The Speed Typing Test 2000 version 3.3* was used to monitor the typists' accuracy and words per minute. The Speed Typing Test 2000 allowed monitoring of the typists when at individual testing intervals. The program allows input of standardized documents for each participant's test. Documents used were randomly selected from www.findarticles.com (documents are references 26 through 41). Both typing speed and accuracy can be measured using this program.

Demographic Questionnaire

A demographic questionnaire (Appendix B) was administered to collect basic information about the participants. The questionnaire was used to determine participant eligibility for the study. Information collected included: age, typing experience, average number of hours typed per day, level of education, and previous or current musculoskeletal injuries related to typing.

Survey of Opinion

A survey (Appendix C) was given to the participants at the completion of the data collection. The survey was also used to measure participant's preference on the style of

*Tested OK Software Ontario, Canada

the keyboard. The participants were asked their opinion on comfort, level of exertion, and overall impression for each keyboard.

Procedures

A pilot study was conducted to determine the exact procedures to be used in the research study. Due to the small sample size of the pilot study, the data collected did not allow the *a priori* calculation of statistical power and optimal sample size. The procedures of both the pilot study and the actual study consisted of 3 baseline measurements of productivity and accuracy during the use of a standard keyboard. These measurements were taken for 5 minutes each, followed by 3 minute breaks between measurements. Once 3 measurements were taken during data collection, of the actual study, 3 Intraclass Correlation Coefficients (ICC) were calculated. An ICC of .988 for accuracy and .990 for gross words per minute were calculated showing very high reliability among the 3 measurements on the standard keyboard. A baseline measurement was then taken on the alternative keyboard for a 5 minute period. The participants then continued to type on the alternative keyboard for 60 minutes. During the 60 minute typing period on the alternative keyboard, 12 measurements of words per minute and accuracy were taken at 5 minute intervals for 5 minutes. The typists were typing continuously for 65 minutes. At the time of data collection, typing speed and accuracy were recorded while typing the standardized documents.

Prior to the data collection, each participant completed a demographic questionnaire. Once eligibility had been established, each participant was asked to sign a written consent form (Appendix D) confirming that they understood the risks and potential benefits involved in the study. Testing sessions were conducted in the same

isolated room away from possible work-place distractions, including answering the phone, other assignments, or coworker disturbances. The participants typed at an ergonomically designed work station using standardized documents.

Measurements of net and gross words per minute, and accuracy were recorded by the Speed Typing Test 2000 software. Gross words per minute was the total number of words typed in one minute's time. Accuracy was defined by the number of mistakes the typists made while adjusting to the alternative keyboard. Net words per minute was words per minute and accuracy combined. Baseline typing measurements of words per minute (net and gross) and accuracy were taken on the standard keyboard. Data collection of words per minute and accuracy occurred at 5 minute intervals. During the 5 minute interval, data from five minutes of typing, from the standardized documents, was collected (see Appendix E for timeline of data collection). Typists typed for a total of 15 minutes on the standard keyboard and 65 minutes on the alternative keyboard (baseline measurement and 12 measurements). After completion of the data collection, each participant completed the survey regarding their opinions of the keyboards used (Appendix C).

Data Analysis

The purpose of this study was to determine whether typists were able to return to their original productivity and accuracy levels when changing from a standard keyboard to a split-angled keyboard. The independent variable was the type of keyboard being used (standard or alternative), and the dependent variables for the study were: (1) gross words typed per minute, (2) net words per minute, and (3) accuracy.

Seven inferential procedures were performed on the data collected. Three paired *t*-tests were performed to compare the baseline measurements of gross and net words per minute and accuracy on the standard keyboard to the baseline on the alternative keyboard. Another 3 paired *t*-tests were performed to compare the baseline measurements of gross and net words per minute and accuracy on the standard keyboard to the peak measurements recorded within 65 minutes of typing on the alternative keyboard (6 paired *t*-tests were performed in total). Two multiple paired t-tests were performed with the Bonferroni Correction to compare baseline gross words per minute (wpm) to typing after 10 minutes and 15 minutes on the alternative keyboard. Two post-hoc power analyses were conducted on the two multiple paired t-tests using the Stata 9.2/SE.* Descriptive statistics were calculated to determine the time intervals, peak gross wpm, peak net wpm, and peak accuracy that typists were able to achieve on the alternative keyboard. For all tests, the alpha level was set at .05 *a priori*. All tests were performed using SPSS version 14.0.†

RESULTS

Thirteen female subjects ranging in age from 27 to 61 years old participated in this study (N=13, $\bar{x}$ =40.8). Of these 13 subjects, typing experience ranged 7 years to 35 years ($\bar{x}$ =21.7). The subjects were tested in a controlled environment to limit external influences on typing speed and accuracy. Each of the subjects typed at a desk that was ergonomically adjusted for them and typed the same documents in the same sequence. The demographic information on the 13 subjects is presented in Table 1.

*StataCorp. 4905 Lakeway Dr, College Station, TX 77845
†SPSS Inc. 233 S. Wacker Dr, Chicago, IL 60606

Three paired *t*-tests were used to determine if there was a significant difference in both gross and net words per minute, and accuracy when changing to an alternative keyboard from a standard keyboard. The baseline results of the typists on both the standard and the alternative keyboard were shown in Table 2. The gross wpm was significantly higher on the standard keyboard than on the baseline measurement on the alternative keyboard (t_{12}=7.846, p=.000). There was no significant difference between the baseline accuracy on the standard keyboard and the alternative keyboard (t_{12}=1.094, p=.295). The net words per minute on the standard keyboard was significantly higher than on the alternative keyboard (t_{12}=7.255, p=.000). The comparison between the baseline measurements on the standard keyboard to the alternative keyboard are presented in Figure 1, 2, and 3.

The baseline results on the standard keyboard along with the peak typing speed and accuracy on the alternative keyboard are presented in Table 3. Three paired *t*-tests were used to determine if there was a significant difference in net words per minute, gross words per minute, and accuracy after typing 65 minutes on an alternative keyboard compared to a standard keyboard. There was a significant difference between the baseline measurement of gross wpm on the standard keyboard and the peak wpm on the alternative keyboard (t_{12}=4.815, p=.000). The second paired *t*-test demonstrated no significant difference between the standard keyboard accuracy and peak accuracy on the alternative keyboard (t_{12}=1.999, p=.069). There was a significant difference in net wpm on the standard keyboard and the alternative keyboard (t_{12}=4.622, p=.001). The significant difference in net wpm was less then the significant difference in gross wpm.

The comparison between baseline measurements on the standard keyboard to the peak measurements on the alternative keyboard are presented in Figures 4, 5, and 6.

Multiple paired *t*-tests with a Bonferroni Correction were performed to determine whether or not there was a significant difference in gross wpm between the 5 minute typing periods on the alternative keyboard. The Bonferroni Correction was used to decrease the chance of committing a type 1 error. Within 15 minutes of typing on the alternative keyboard, there was a marked increase in words per minute typed. The paired *t*-test comparing the baseline measurement and the 10 minute measurement on the alternative keyboard, demonstrated no significant difference in gross wpm (t_{12}=1.997, p=.069). The paired *t*-test comparing the baseline measurement and the 15 minute measurement on the alternative keyboard, demonstrated a significant difference in gross words per minute (t_{12}=3.880, p=.002), independent subjects demonstrated improvements in typing productivity at the 15 minute mark. From visual inspection of the Figures 7 and 8 we concluded that at approximately the 40 minute mark, typists on average did not continue to make gains in words per minute.

Two post hoc power analyses were performed to determine the whether or not the power of the study was high enough to rule out the risk of committing Type II error. The first post-hoc power analysis was used to determine the power between the baseline measurement and the 10 minute measurement for wpm when typing on an alterative keyboard. This power of this test was 0.9. The second post-hoc power analysis was used to determine the power between the baseline measurement and the 15 minute measurement for wpm on the alternative keyboard. The power of this test was also 0.9. The risk of committing a Type II error in either of these analyses was 10%.

Figures 7 through 9 display the progression of words per minute and accuracy over the 65 minute time period while typing on the alternative keyboard. Figure 10 presents both net words per minute and gross words per minute while typing on the alternative keyboard. This figure shows the overall productivity (words per minute combined with accuracy) compared to the gross words per minute (independent of accuracy). Figure 11 presents a comparision of the 3 baseline measurements of gross wpm on the standard keyboard to the 13 measurement of gross wpm on the alternative keyboard.

None of the typists reached their original productivity when typing on the alternative keyboard. The mean peak gross words per minute on the alternative keyboard was 43.97±9.51. The mean peak net words per minute on the alternative keyboard was 43.06±9.47. The mean peak accuracy on the alternative keyboard was 98.76%± .826. The mean peak accuracy reached on the alternative keyboard was higher numerically than that of the standard keyboard; however, statically there is no significant difference. (Table 4) The average time that typists reached their peak gross words per minute was 48.46±10.48 minutes, ranging from 25 minutes to 65 minutes ($\bar{x}$ =48.46, SD=10.48). With a confidence interval of 95%, the peak gross words per minute will be reached between 42.53 and 54.39 minutes of typing on the alternative keyboard. Subjects were able to reach their peak net words per minute in an average time of 48.85 ±9.69 minutes, ranging from 25 minutes to 65 minutes ($\bar{x}$ = 48.85, SD=9.69). With a confidence interval of 95 percent, the peak net words per minute will be reached between 43.37 and 54.33 minutes of typing on the alternative keyboard. Subjects were able to reach their peak accuracy in an average time of 40±21.21 minutes, ranging from 10 minutes to 65 minutes

($\bar{x}$ = 40, SD=21.21). With a confidence interval of 95 percent, the peak accuracy will be reached between 28 and 52 minutes of typing on the alternative keyboard.

DISCUSSION

The purpose of this study was to determine whether or not experienced typists would be able to return to original words per minute and accuracy when switching to an alternative keyboard within a 65 minute session. Experienced typists required more than one hour of typing on an alternative keyboard to come very close to returning to original productivity on a standard keyboard. However dramatic improvements were achieved within this time period. Even though subjects were not able to reach original words per minute, typists were able to not only reach original accuracy, but also exceed original accuracy. On average the subjects were able to exceed the original accuracy scores within 40 minutes of typing. There no statistical difference in typing speed after 10 minutes on the alternative keyboard; however, functionally there were improvements in the number of wpm. After typing for 15 minutes, on the alternative keyboard, there was both a statically significant difference and functional improvements in wpm. After 40 minutes of typing on the alternative keyboards, there was no increase in peak wpm possibly due to fatigue.

These results both confirm and contradict the work of previous researchers. In a study conducted by Simoneau and Marklin, just 6 minutes was the time required by experienced typists to return to their original productivity levels.[5] However in other study conducted by Marklin and Simoneau, 20 hours of typing on an alternative keyboard was required before experienced typists returned to original productivity and accuracy.[6] In our study, the typists did not reach full productivity, but were able to reach

approximately 85% productivity with in 65 minutes of typing. The information from current research and from this study are not conclusive; more research is required to determine the exact time interval required by experienced typists to return to original productivity.

These results are clinically relevant to experienced typists that type a minimum of 2 hours per day using the 10 finger typing method and do not have any current musculoskeletal injuries. All of the participants typed primarily on a standard keyboard. The participants did not have any current musculoskeletal injuries at the wrist. As such we did not examine the effects of musculoskeletal injuries at the wrist and productivity on the alternative keyboard.

On an average these subjects reached approximately 85% of original wpm after typing 65 minutes on the alternative keyboard (7.86 fewer gross words per minute and 7.56 fewer net words per minute). Although this may influence productivity during a work day the benefits from using the alternative keyboard may out weigh the decrease in productivity. For a double spaced page, there are approximately 280 words. With a decline of 7.86 words per minute and typing 2 to 4 hours per day, a typist at this level of experience on the alternative keyboard can expect to decline 943.2 to 1886.4 words. A decline in this many words is equivalent to approximately 3.37 to 6.74 pages, in a 2 to 4 hour period. Employees may be hesitant to change due to the loss of productivity; however, the use of alternative keyboards may decrease the prevalence of WRMDs at the wrist. By implementing an alternative keyboard, research has shown there is a potential for reduced time away from work and employer savings.

There is no consistent approach or standard for requirements of employment of typists. For the benefit of this study, net and gross words per minute, along with accuracy were recorded for a purpose of completeness of measuring productivity. After exploring job requirements for Administrative Assistants, the typical range for minimal requirements were approximately 35 to 50 wpm with 3 to 5 errors in a 5 minute period, although the actual thresholds vary by company. On average these typists were able to reach an average of 43.97±9.51 gross words per minute and 43.06±9.47 net words per minute on an alternative keyboard after 65 minutes of typing.

Although a significant difference in wpm was not found after 65 minutes of typing on the alternative keyboards, drastic improvements words per minute was accomplished over this small time period. After 5 minutes of typing, on the alternative keyboard, on average there was a drop in gross words per minute by 21.26 wpm (21.71 net wpm). However, on average, subjects reached their peak gross wpm with a time period of 48.46 minutes (48.85 minutes for net wpm) with only a decrease of 7.86 gross wpm (7.56 net wpm). Since subjects were able to show improvements within a 65 minute time period, it is hypothesized that with more practice typing on the alternative keyboard, typists would return to original productivity.

There were several limitations to this study which may have influenced the results. One potential limitation is a fatigue factor. A majority of the subjects reach their peak typing speed between 25 and 65 minutes. Once typists reached their peak speed, their typing speed declined for the remainder of the typing period. A factor that may have influenced this data was typist's fatigue level. In a typical day, typists often take frequent breaks due to the phone ringing, meetings, and speaking with other employees. In future

studies, the time period during which data are recorded should be shortened and collected over multiple days to try to moderate the fatigue factor.

Another limitation of the study was the subject's comfort level using the alternative keyboard. Many of the subjects reported feeling uncomfortable using the alternative keyboard. While typing on the alternative keyboard, most typists stated that it was hard to get comfortable typing, and that their bodies were more tense with use of the alternative keyboard. Also a majority of the typists stated that they prefer the standard keyboard over the alternative keyboard because of experience and time spent on the standard keyboard. Six out of the 13 subjects felt that the alternative keyboard required more force to type then the standard keyboard. In future studies, a comprehensive evaluation and structured approach to measuring subjects' comfort should be included to account for the potential influence on productivity.

After analyzing the data we realized there may have been a difference in typing difficulty between the typing documents. For instance, at the 45 minute mark there was both a drastic drop in gross words per minute and accuracy (Refer to Figures 8 and 9). This drastic drop was also evident in the net words per minute at the 45 minute mark. The drastic drop could be accounted for by the difficulty of the document that was consistent for all typists. Two possible variables that may have influenced this was the increased amount of numerics and word difficulty. Some typists reported having difficulty typing the letters "b" and "n" due to the change in finger position on the alternative keyboard. Since the difficulty of the documents varies and cannot be determined, this could be a possible limitation of the study. However, the repeated use of

the same document throughout the entirety of the test would not be an accurate measure of productivity due to the familiarity of the document.

Another possible limitation of this study is the length of time eluded for this study was not sufficient for typists to return to baseline wpm. We found that 65 minutes of typing on an alternative keyboard was not sufficient. Future studies should increase the overall time in which typists are recorded typing on the alternative keyboards. By increasing the overall time period time of typing on the alternative keyboard, the exact time in which typists reach original productivity could be determined. Future studies should also determine if there is a correlation between years of experience of typists and how quickly one is able to adapt to an alternative keyboard.

Even though there are benefits from changing to alternative keyboards many experienced typists are still using standard keyboards. Typing on standard keyboards forces a typist's wrists into a non-neutral position that increases the risk of musculoskeletal injuries. Clinically, physical therapists will continue to see patients with carpal tunnel, tendonitis, and other typing related injuries. It will be the physical therapists' obligation to educate patients about the potential benefits from using an alternative keyboard. Even though alternative keyboards have the potential to decrease the prevalence of musculoskeletal injuries at the wrist of experienced typists, more studies need to be conducted to determine when typists will return to original productivity and accuracy. When this time interval is determined, typists will be able to efficiently and effectively transition to an alternative keyboard, while potentially decreasing the risk for developing WRMDs. This study supports the ability of physical therapists to advise that typists are likely to able to see an approximately 15% loss of

words per minute and no loss of accuracy within an hour of switching to an alternative keyboard.

CONCLUSION

Typist often experience musculoskeletal injuries related to typing. Alternative keyboards have been developed to reduce the risk for these injuries; however, typists sometimes resist changing to alternative keyboards because of concerns of the potential to reduce productivity. This study sought to determine whether or not experienced typists were able to return to original productivity and accuracy when changing to an alternative keyboard. Since 100% of the subjects did not reach original productivity, more research is required to determine factors that influence whether an experienced typist will regain original productivity on the alternative keyboard. These studies may also be able to determine the time periods of such a return to baseline productivity and accuracy. Once the time period has been established, it would be helpful to determine training requirements and to convince typists to try alternative keyboards.

ACKNOWLEDGEMENT PAGE

We, the researchers, wish to acknowledge the assistance of Dr. David Miller, our advisor, for his guidance and support. Also, we would like to a thank Dr. Julia Chevan for her statistical expertise, Tom Bianco for being our reader, and Cindy Moriarty for helping us to recruit subjects. We also would like to acknowledge our family and friends for their support. Lastly, this study would not have been possible without the assistance of our subjects who not only provided us with the data but insight on their experiences with typing.

REFERENCES

1. Fisher TF, Konkel SR, Harvey C. Musculoskeletal injuries associated with selected university staff and faculty in an office environment. *Work: J Prev, Assess Rehab.* 2004:4:195-205.

2. Boudreau LA, Wright GW. Ergonomic considerations for a patient presenting with a work-related musculoskeletal disorder: a case report. *J Can Chiropr Assoc.* 2003;47:33-38.

3. Weryder S. Do the math: savvy stock-picking is a myth. *Business Week.* 2006;20:1-4.

4. Dambro MR. *Griffith's 5-Minute Clinical Consult.* New York: Lippincott Williams & Wilkins; 2005.

5. Marklin RW, Simoneau GG. Design features of alternative computer keyboards: a review of experimental data. *J Orthop Sports Phys Ther.* 2004;34:638-649.

6. Marklin RW, Simoneau GG, Monroe JF. Wrist and forearm posture from typing on split and vertically inclined computer keyboards. *Hum Factors.*1999;41:559-569.

7. Smith MJ, Karsh BT, Conway FT, et al. Effects of a split keyboard design and wrist rest on performance, posture, comfort. *Hum Factors.* 1998;40:324-336.

8. Swanson NG, Galinsky TL. The impact of keyboard design on comfort and productivity in a test-entry task. *Appl Ergonomics.* 1997;28:9-16.

9. Simoneau GG, Marklin RW. Effect of computer keyboard slope and height on wrist extension angle. *Hum Factors.* 2001;43:287-298.

10. Chang C, Wang J, Luh J, Hwang Y. Development of a monitoring system for keyboard users' performance. *Ergonomics.* 2004;47:1571-1581.

11. Lowe BD. Accuracy and validity of observational estimates of wrist and forearm posture. *Ergonomics.* 2004;47:527-554.

12. Jacobs K. *Ergonomics for Therapists.* Boston, MA:Butterworth Heinemann;1999.

13. Omer SR, Ozcan E, Karan A, Ketenci A. Musculoskeletal system disorders in computer users: effectiveness training and exercise programs. *J Back Musculoskeletal Rehabil.* 2004;17:9-13.

14. Liao M, Drury CG. Posture, discomfort and performance in a VDT task. *Ergonomics.* 2000;43:345-359.

15. Lueder R, Grant C. Ergonomics of alternative keyboards. Office Ergonomics Training Web site. 2002. Available at: http://office-ergo.com/12things2.htm. Accessed March 29, 2006.

16. Moore KL, Dalley AF. *Clinically Oriented Anatomy*, 4th ed. Baltimore Md: Lippincott Williams & Wilkins; 1999.

17. Computer comfort. *USA Today*. 1995;123:94.

18. Marklin RW. Effect of setup configurations of split computer keyboards on wrist angle. *Phys Ther.* 2001;81:1038.

19. Barr A, Barbe MF. Pathophysiological tissue changes associated with repetitive movement: a review of the evidence. *Phys Ther.* 2002;82:173-184.

20. The datahand basics. *DataHand Systems*. 2005. Available at: http:// www.datahand.com/overview/overinst.htm. Accessed on March 29, 2006.

21. Smith MJ, Bayehi AD. Do ergonomics improvements increase computer workers' productivity?: an intervention study in a call centre. *Ergonomics.* 2003;46:3-17.

22. Simoneau GG, Marklin RW, Berman JE. Effect of computer keyboard slope on wrist position and forearm electromyography of typists without musculoskeletal disorders. *Phys Ther.* 2003;83:816-830.

23. Keller E, Fleischer R, Strasser H. Estimated and experienced subjective assessment of the ergonomic quality of a keyboard. *Occup Ergonomics*. 2004;4:121-131.

24. Zecevic A, Miller DI, Harburn K. An evaluation of the ergonomics of three computer keyboards. *Ergonomics*. 2000;43:55-72.

25. Baker NA, Redfern MS. Developing an observational instrument to evaluate personal computer keyboarding style. *Appl Ergonomics.* 2005;36:345-354.

26. When and Why Did Grand Canyon Become a National Park? Grand Canyon National Park Web site. [serial online]. 2005. Available at: http://www.nps.gov/archive/ grca/grandcanyon/quicklook/national park.htm. Accessed January 30, 2007.

27. Travis J. Human-cloning claim creates controversy-advanced cell technology research. *Science News.* [serial online]. 2001. Available at: http://www.findarticles.com/p/articles/mi_m1200/ is_22_160/ai_81764372. Accessed January 30, 2007.

28. Border crossing: it's not realistic to think about deporting 11 million illegal immigrants. *Christian Century.* [serial online]. 2006. Available at: http://www.findarticles.com/p/articles/mi_m1058/is_4_123/ai_n16439624. Accessed January 30, 2007.

29. Summers A. The jaws that jump: trap-jaw ants have smashed the record for fastest predatory strike on earth, with mandibles that double as spring launchers. *Natural History* [serial online]. 2006. Available at: http://www.findarticles.com/p/articles/mi_m1134/is_10_115/ai_n16883026. Accessed January 30, 2007.

30. Bender M. Moody? Unmotivated? The best advice you'll ever get: new research sheds light on how you can defend yourself against one of the top women's health threats—depression. Shape [serial online]. Available at: http://www.findarticles.com/p/articles/mi_m0846/is_8_25/ai_n16118816/pg_2. Accessed January 30, 2007.

31. Seppa N. Self help: stem cells rescue lupus patients. Science News [serial online]. 2006. Available at: http://www.findarticles.com/p/articles/mi_m1200/is_5_169/ai_n16084211. Accessed January 30, 2007.

32. Kathy M. Preventing child abuse through the schools - community programs in McKee Rocks and Stowe Township, Pennsylvania, aid in child abuse prevention - includes related material. Children Today [serial online]. 1992. Available at: http://findarticles.com/p/articles/mi_m1053/is_n2_v21/ai_13561082/pg_2. Accessed January 30, 2007.

33. Klimley AP, Hinto M, Martin RA, Martin A, Jaws-or lips? *Natural History*[serial online]. 2006. Availabet at: http://www.findarticles.com/p/articles/mi_m1134/is_10_115/ai_n16883014. Accessed February 8, 2007.

34. Rao J. The sky in December and January. *Natural History* [serial online]. 2006. Available at: http://www.findarticles.com/p/articles/mi_m1134/is_10_115/ai_n16883030. Accessed February 8, 2007.

35. Osborne T, Osborne L. Big bird: the kori bustard, the world's heaviest flyer, depends on the rain on the Namibian plain for its breeding, success. Natural History [serial online]. Available at: http://www.findarticles.com/p/articles/mi_m1134/is_10_115/ai_n16883027. Accessed February 8, 2007.

36. Crowley S. Bilateral breathing for young swimmers. Swimming Technique [serial online]. 2005. Available at: http://findarticles.com/p/articles/mi_qa3871/is_200501/ai_n9473833. Accessed February 8, 2007.

37. Brooks M. BOWMAN on swimming...and Phelps. Swimming Technique [serial online]. 2005. Available at: http://findarticles.com/p/articles/mi_qa3871/is_200501/ai_n9473834. Accessed February 8, 2007.

38. Wallace S. Rites of passage. Camping Magazine [serial online]. 2006. Available at: http://findarticles.com/p/articles/mi_m1249/is_3_79/ai_n16608948. Accessed February 8, 2007.

39. Young TD. Factors effecting exercise adherence. *American Fitness* [serial online]. 2005. Available at: http://www.findarticles.com/p/articles/mi_m0675/ is_1_23/ai_n9485471. Acessed on February 20, 2007.

40. Hunter LP. Outsmart breast cancer: from exercise to leafy greens, here's an update on ways to decrease your risk. *Essence*. 2005. Available at: http://www.findarticles.com /p/articles/mi_m1264/is_6_35/ai_n15635327. Accessed February 20, 2007.

41. Perlman KCP. The gardening gourmet-gardening techniques. *Flower & Garden Magazine*. [serial online]. 2002. Available: http://www.findarticles.com/p/articles/mi_m1082/is_2_46/ai_87779987. Accessed on February 20, 2007.

TABLES/FIGURES

Table 1.
Demographic Representation of Participants (n=13).

	Age	Hours Typed Per Day	Years Experience
Subject 1	28	4+	16
Subject 2	40	4+	20
Subject 3	43	2-4	20
Subject 4	53	2-4	30+
Subject 5	53	4+	30
Subject 6	48	4+	27
Subject 7	40	2-4	20
Subject 8	48	4+	20
Subject 9	46	4+	*
Subject 10	61	2	15
Subject 11	27	4+	7
Subject 12	45	2-4	30
Subject 13	51	4+	25

*Subject did not report years of experience.

Table 2.
Comparison of Baseline Measurements on the Standard and Alternative Keyboard (n=13).

	Standard Keyboard		Alternative Keyboard		P
	$\bar{x}$	SD	$\bar{x}$	SD	
Gross WPM*	51.83	12.39	43.97	7.24	.000
Net WPM	50.62	12.80	28.91	7.61	.000
Accuracy	97.29	3.12	94.51	.83	.295

* WPM = words per minute

Table 3.
Comparison of Baseline Measurement on the Standard and Peak Measurement on the Alternative Keyboard (n=13).

	Standard Keyboard		Alternative Keyboard		P
	$\bar{x}$	SD	Peak $\bar{x}$	SD	
Gross WPM	51.80	12.40	44.29	9.51	.000
Net WPM	50.62	12.80	43.06	9.55	.001
Accuracy	97.29	3.12	98.76	.83	.069

Table 4.
Average Words per Minute and Accuracy on the Alternative Keyboard (n=13).

	Mean	SD	Minimum	Maximum
Peak Gross WPM	43.97	9.51	28.72	62.68
Peak Net WPM	43.06	9.55	27.48	62.52
Peak Accuracy	98.76	.83	97.18	99.74

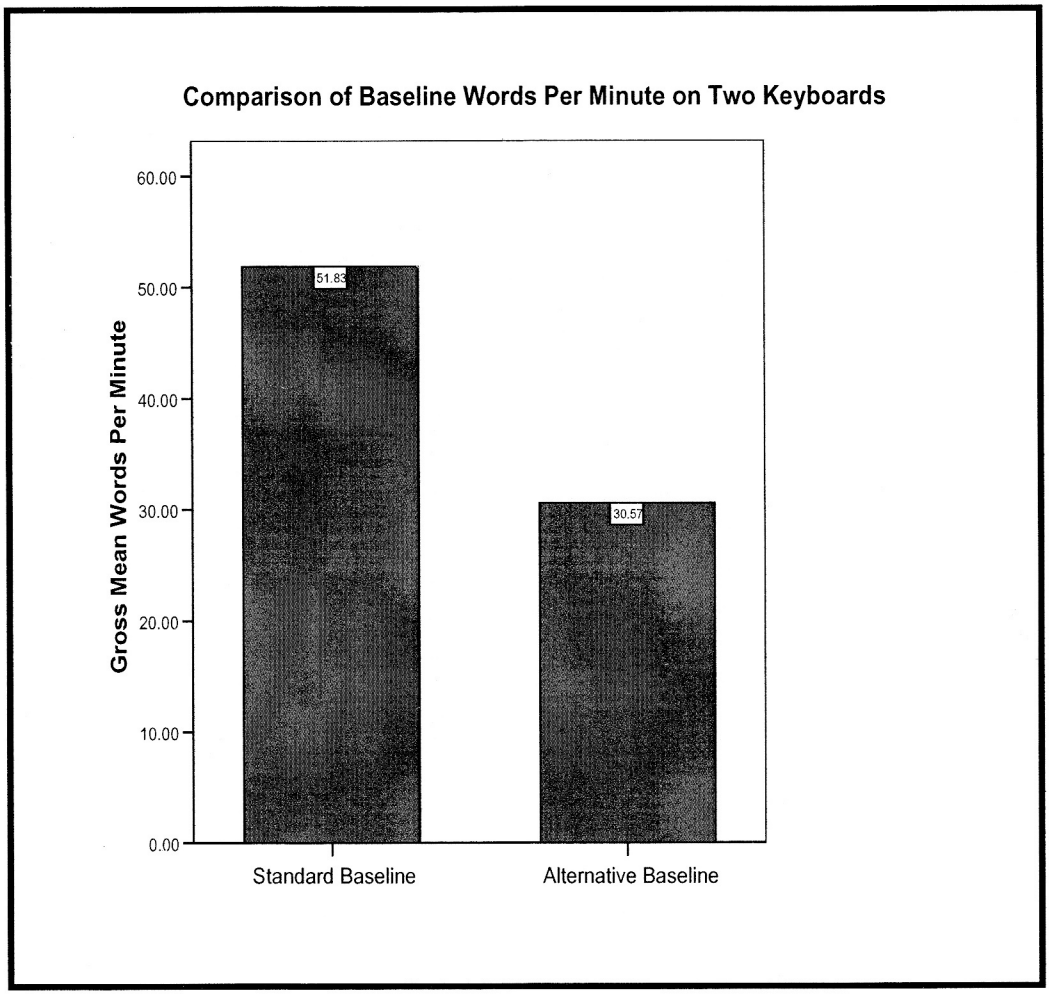

Figure 1.
Baseline words per minute on the standard and alternative keyboard (n=13).

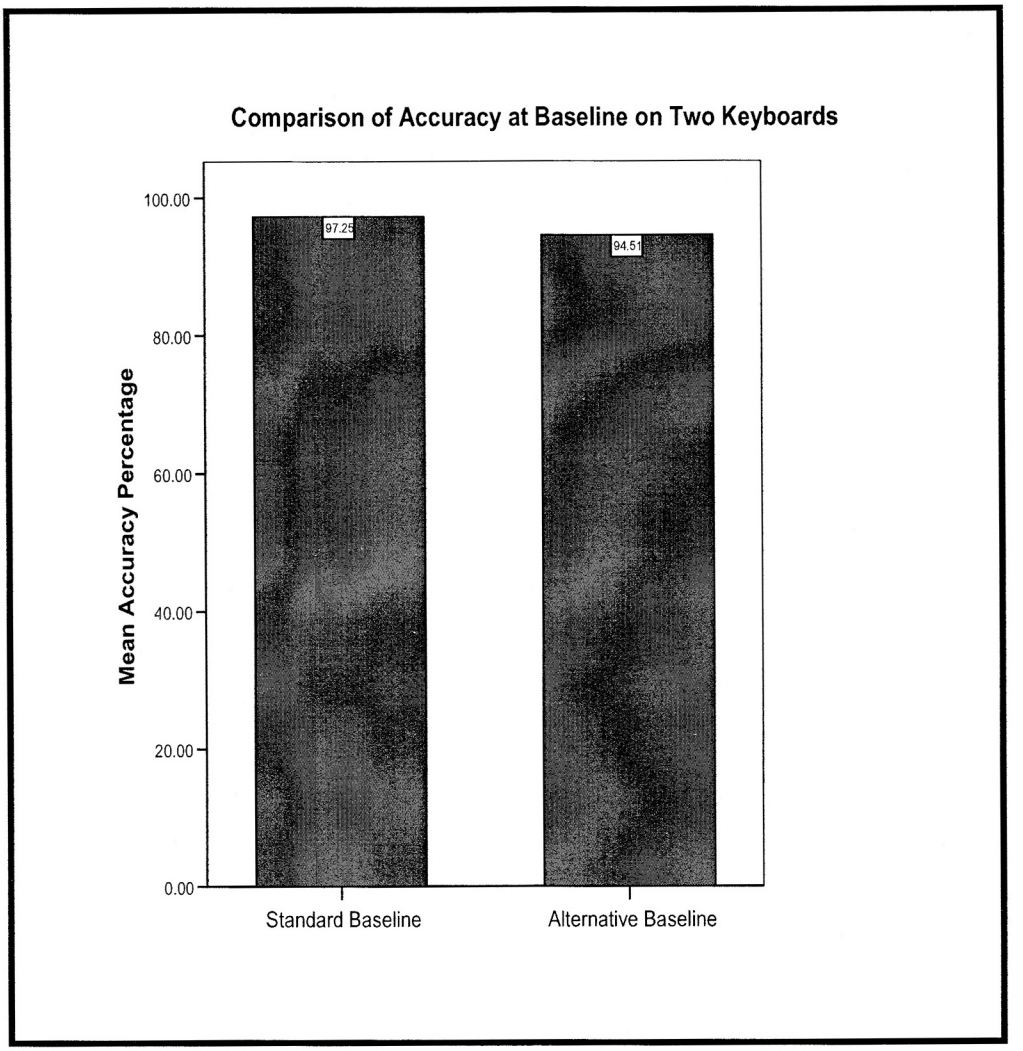

Figure 2.
Baseline accuracy on the standard and alternative keyboards (n=13).

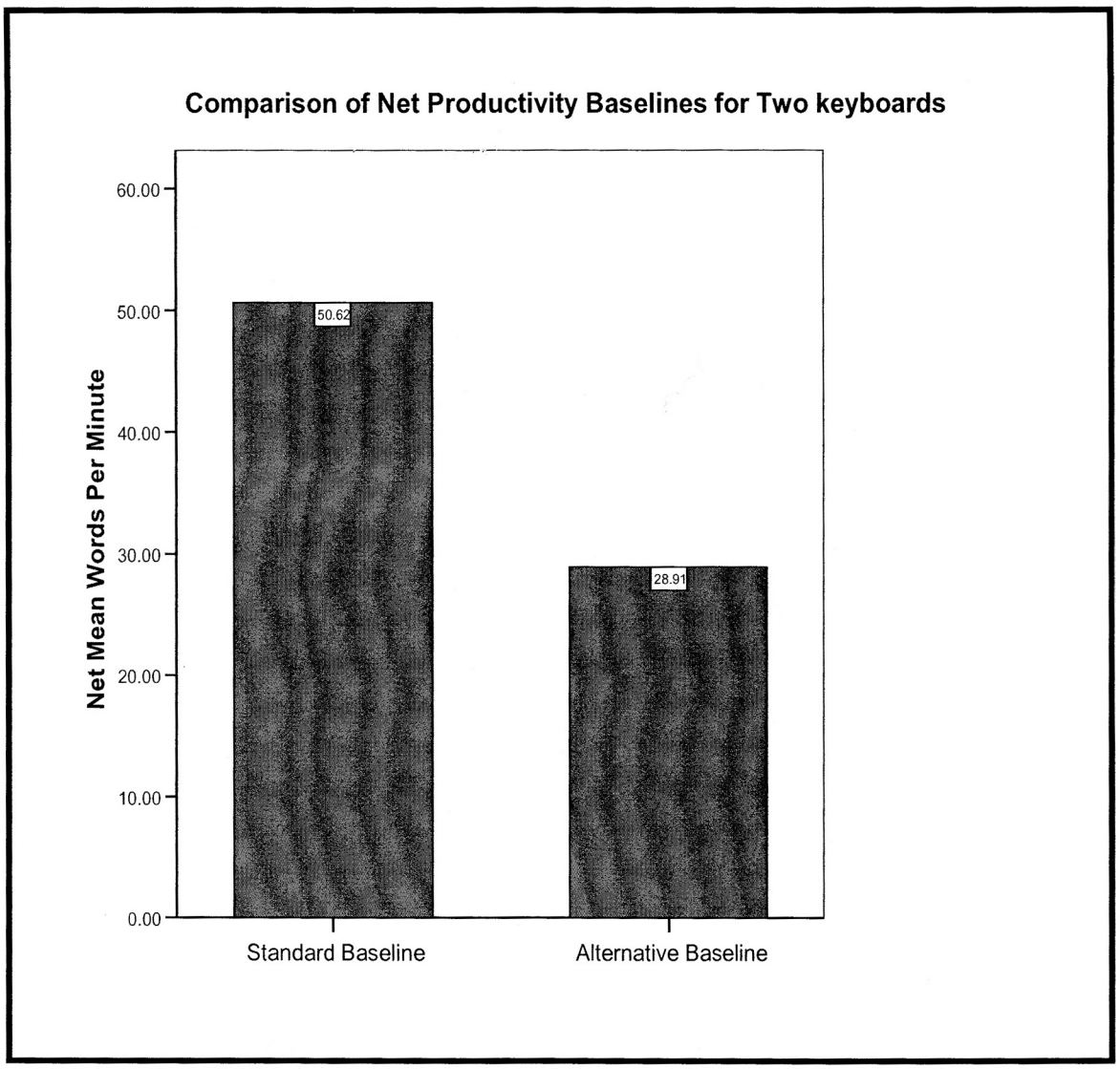

Figure 3.
Baseline net words per minute on the standard and alternative keyboards (n=13).

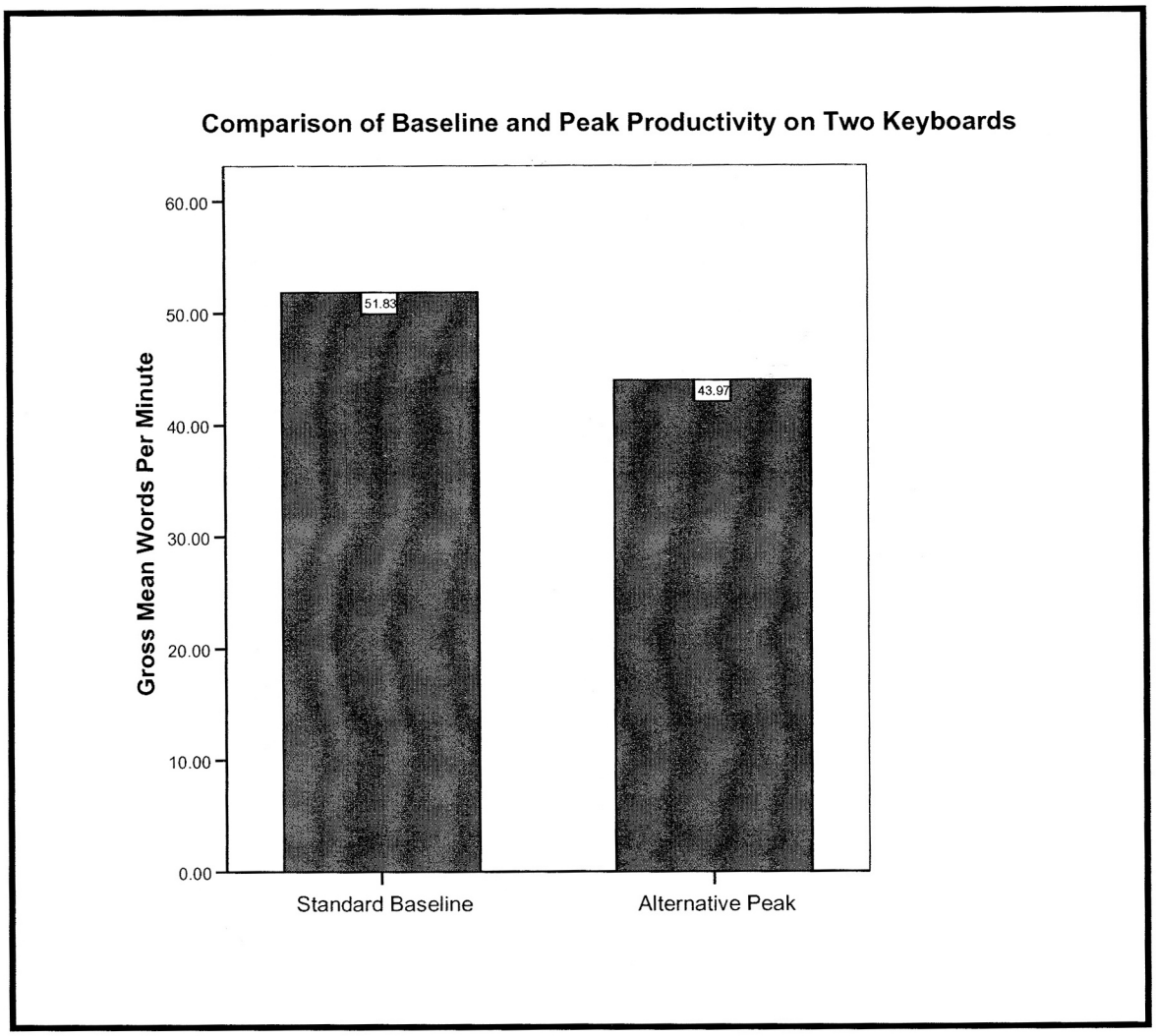

Figure 4.
Baseline gross words per minute on standard keyboard and peak gross words per minute on the alternative keyboard (n=13).

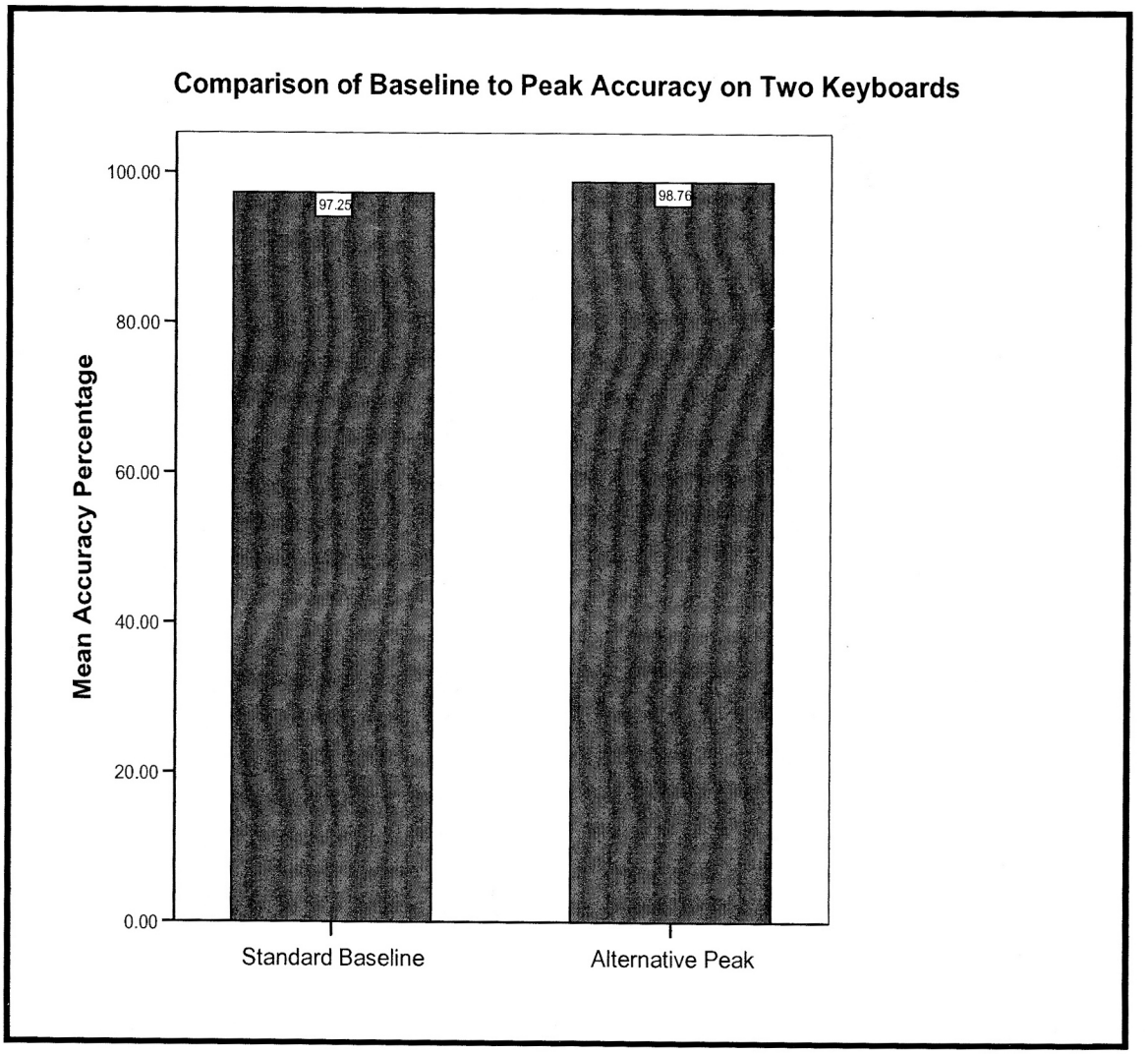

Figure 5.
Baseline accuracy on the standard keyboard and peak accuracy on the alternative keyboard (n=13).

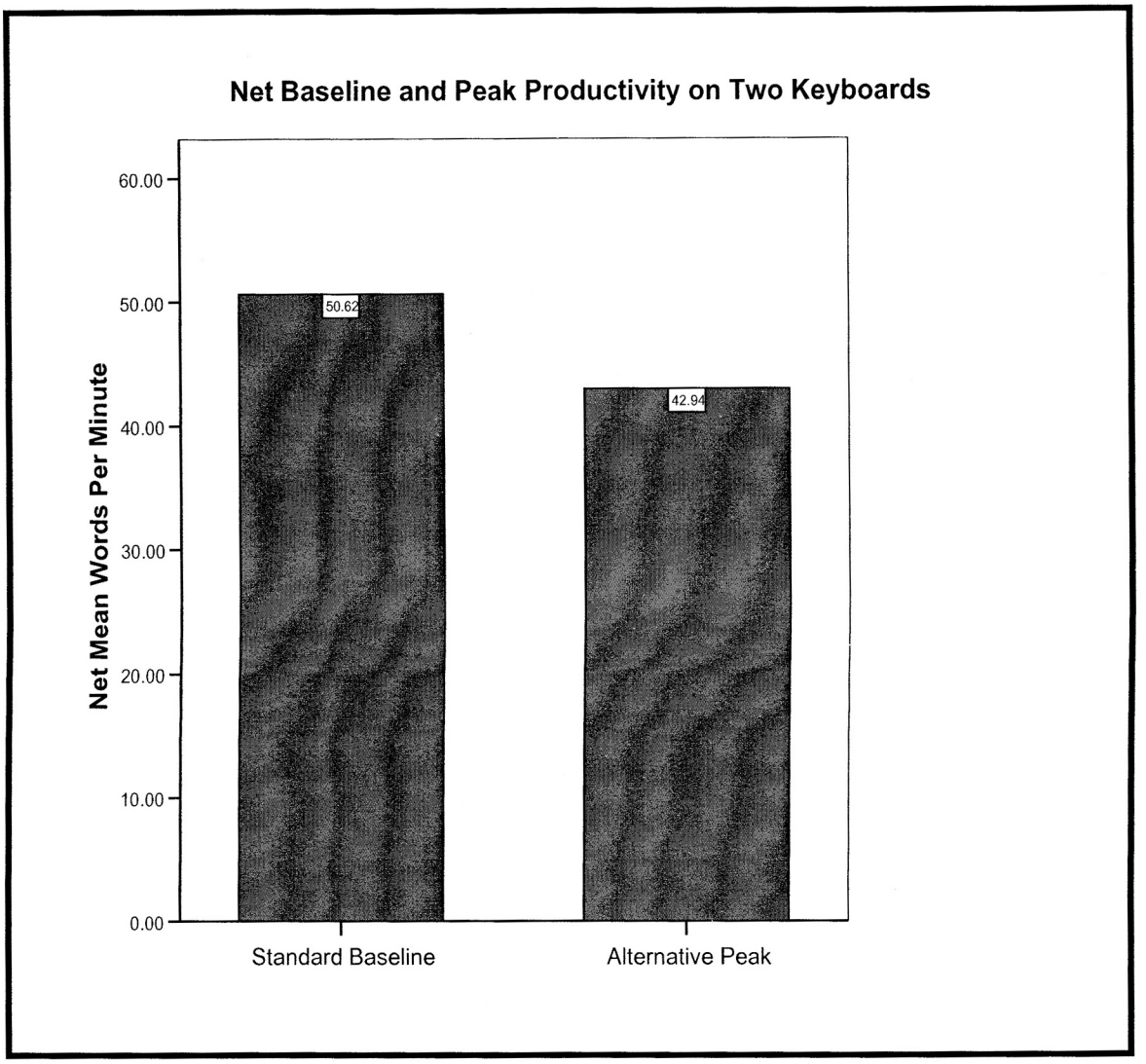

Figure 6.
Baseline net words per minute on the standard keyboard and peak net words per minute on the alternative keyboard (n=13).

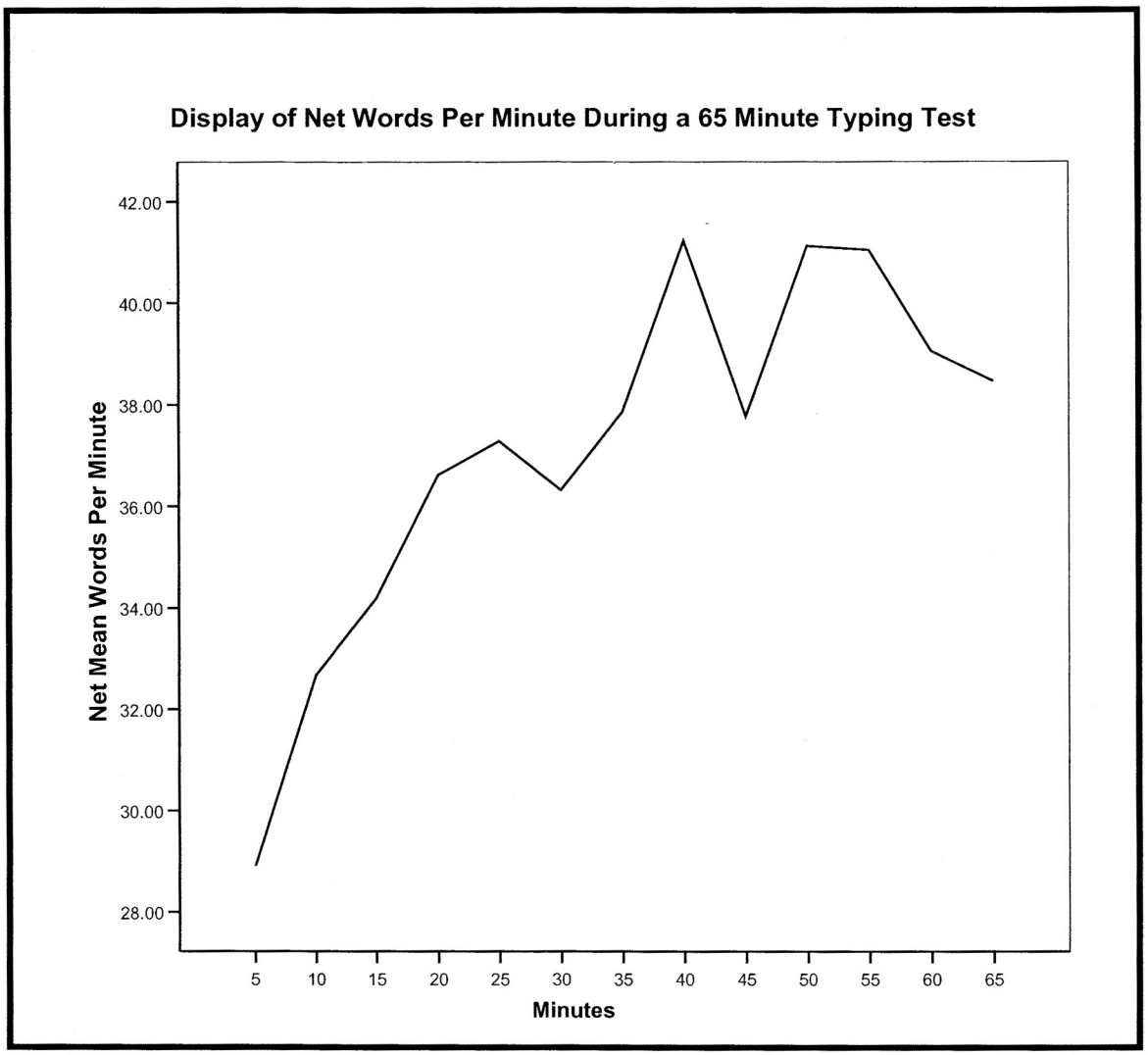

Figure 7.
Mean net words per minute (wpm) over 65 minutes of typing on an alternative keyboard (n=13).

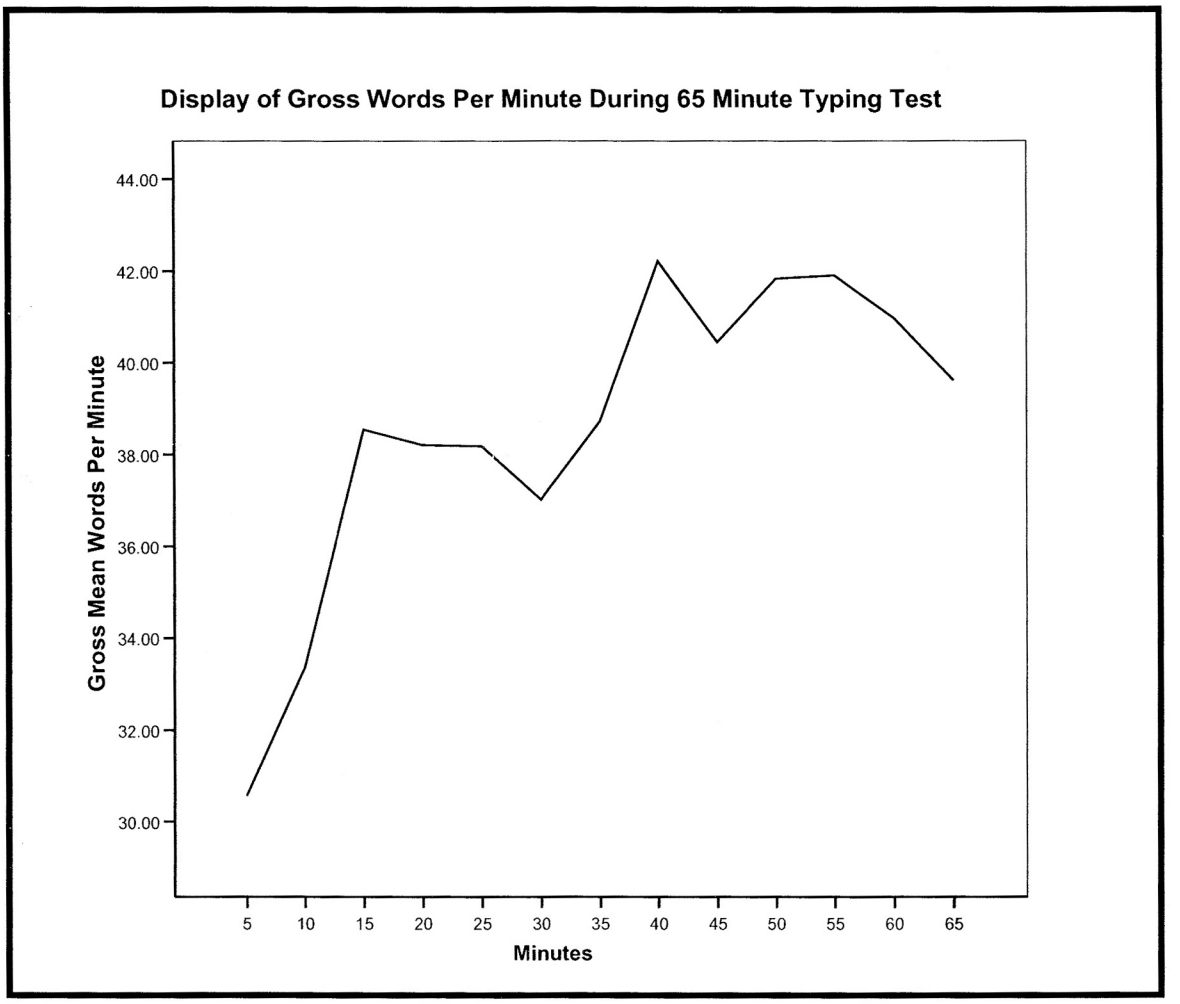

Figure 8.
Mean gross words per minute (wpm) over a typing period of 65 minutes on the alternative keyboard (n=13).

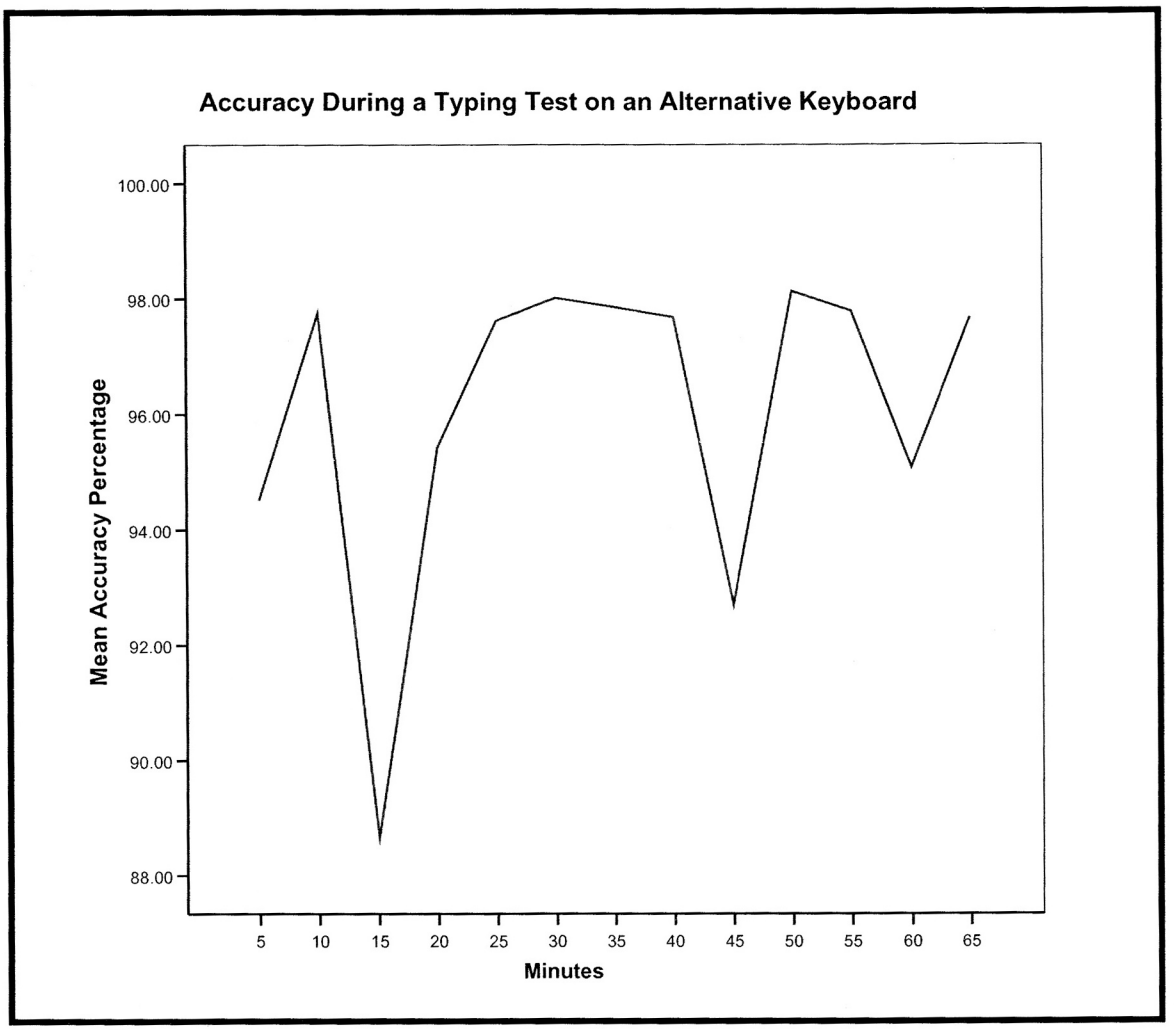

Figure 9.
Mean percentage of accuracy over a typing period of 65 minute on the alternative keyboard (n=13).

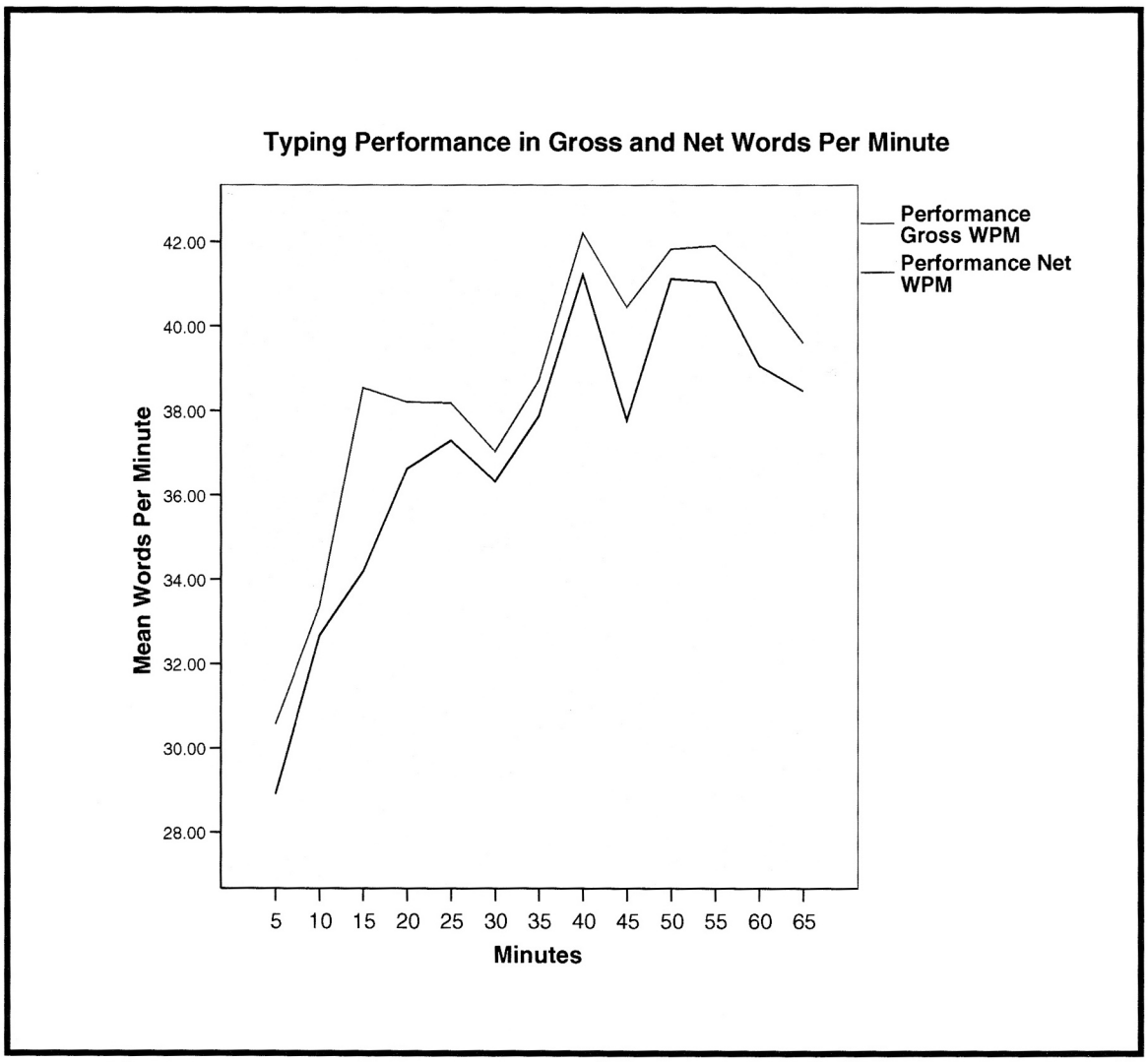

Figure 10.
Comparison between gross and net words per minute over the 65 minute typing period (n=13).

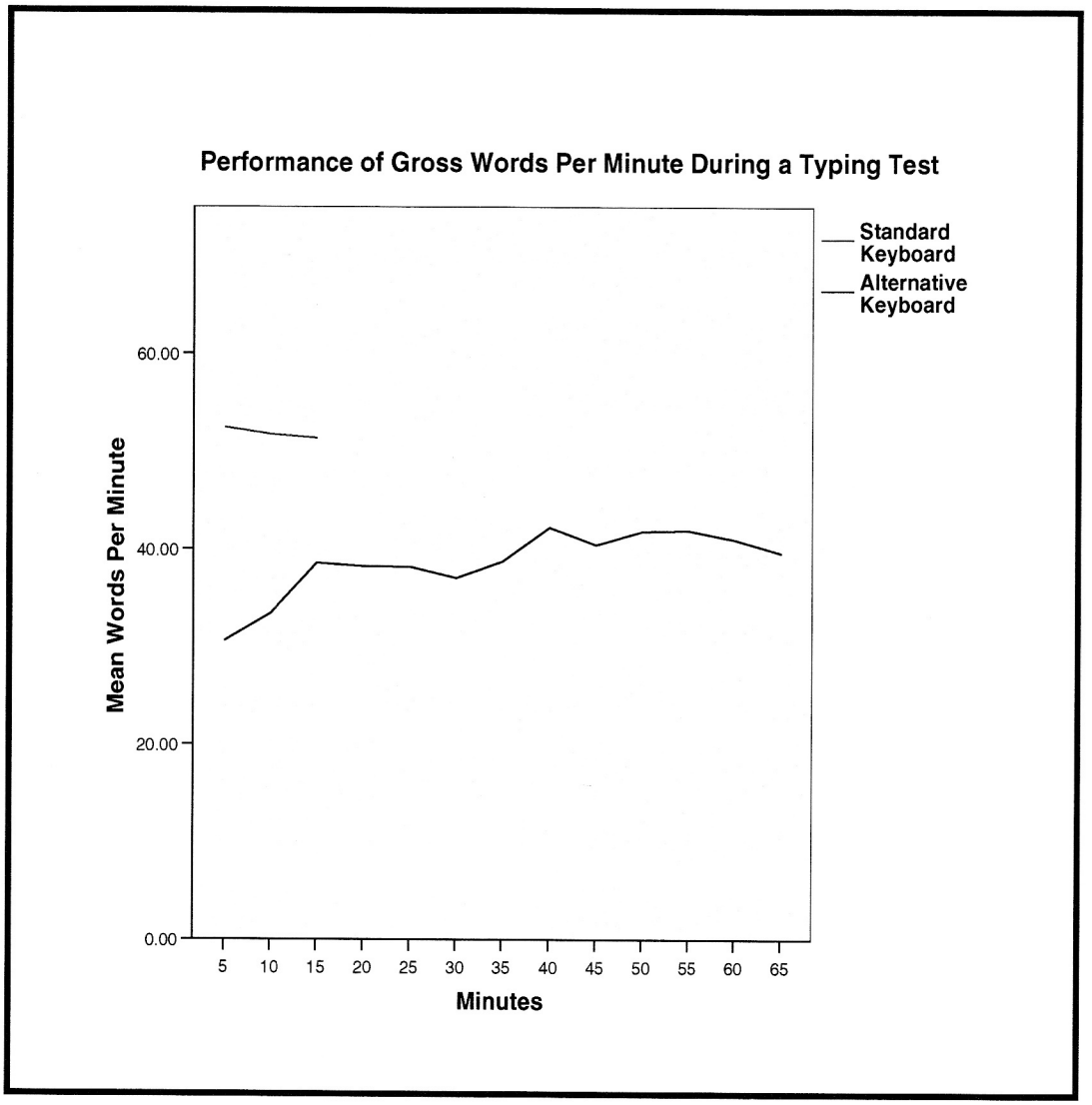

Figure 11.
Comparison of the 3 baseline measurement of gross wpm on the standard keyboard to the 13 measurements of gross wpm on the alternative keyboard (n=13).

APPENDIX A

REVIEW OF LITERATURE

The primary focus of this review of literature is on the potential changes in productivity that might occur when switching from a standard keyboard to an alternative design keyboard. The alternative design keyboard provides a more neutral wrist position while typing. The review also concentrates on the potential for a decreased incidence of work related musculoskeletal injuries.

Technology is increasing in the work place, requiring more typing to be performed by workers.[13] Musculoskeletal injuries are becoming more abundant with the increase in typing.[13] Musculoskeletal injuries that occur in the work place are often called work related musculoskeletal disorders (WRMDs). WRMDs reduce employee performance and productivity. Additionally, musculoskeletal injuries create extra expenses for companies, which could be prevented if successful ergonomic changes are implemented.

Musculoskeletal injuries might be controlled for through the use of ergonomically correct keyboards. A change from a standard keyboard to a more ergonomic design is resisted by employees and employers for possible fear of decreased job performance. Some typists fear that they will not return to the same typing speed they had prior to changing the form of keyboard they use.[3] Companies also hesitate to make a change because of the cost associated with implementing this design.[14]

Musculoskeletal Injuries at the Wrist Associated with Keyboards

Musculoskeletal injuries occur when working in prolonged positions, in which specific movements are repeated. According to the Bureau of Labor Statistics, there are 92,576 reported repetitive trauma cases associated with typing or data entry. Of these

cases 55% affected the wrist, 7% the shoulder, and 6% affected the back.[1] These injuries often result from improper postures involving prolonged, non-neutral positions of the wrist. Non-neutral positions may stretch and compress tendons, nerves, and other tissues at the wrist.[15] The combination of forceful exertions, repetition, mechanical stress, and static positioning can lead to the development of musculoskeletal injuries or disorders.[15] Forceful exertions occurs when typing for prolong periods of time. Mechanical stress results from the external surfaces that result in increased pressure at the wrist. Static positioning results from the position in which the hands are held when typing.[15]

Use of a keyboard for more then 15 hours per week has been identified as a risk factor for musculoskeletal injuries in the upper extremity, shoulder, and neck region.[5] Typing for extreme amounts (up to 100,000 keystrokes per day) while having the wrist in a deviated posture increases the risk for an occupational distal upper extremity musculoskeletal disorders, such as carpal tunnel syndrome and wrist tenosynovitis.[5]

One common location that is affected by typing is the carpal tunnel.[3] The tunnel is formed by the alignment of the carpal bones on 3 sides and the roof of the tunnel is formed by the flexor retinaculum (transverse carpal ligament).[16] The carpal tunnel is the passageway in which 10 structures enter from the forearm into the wrist.[16] The structures include the four tendons from each of the flexor digitorum profundus and the flexor digitorum superficialis muscles, the flexor pollicis longus tendon and the median nerve.

Carpal tunnel syndrome is the most common cause of peripheral nerve compression at the wrist.[4] When the carpal tunnel narrows, the structures become compressed, leading to carpal tunnel syndrome (CTS). The median nerve is the most sensitive structure of the wrist; therefore, it is most commonly affected.[16] The narrowing of this tunnel can result

from edema, inflammation, increased pressure on the tunnel from external surfaces, infection, or fluid retention.[16] Carpal tunnel syndrome may present with burning pain, tingling or prickling sensations in the fingers, arm pain, and weakness of the hand and wrist.[4] This debilitating pain often occurs in people who do extensive data processing, data entry, bookkeeping, and other similar tasks.[3] Surgery is often the only solution to relieve carpal tunnel. Surgery prevents the worker from working during the long recovery period and brings the risk of reoccurrence.[17]

Wrist positions of extreme flexion, extension, ulnar and radial deviation can increase pressure in the carpal tunnel area.[15] Extension of the wrist has been shown to decrease the diameter of the carpal tunnel, potentially increasing the pressure on the median nerve.[15] These positions not only increase the pressure on the median nerve, but in addition, the forearm muscles are required to work in a shortened range which increases muscle fatigue.[15] The effect of wrist extension was more evident on carpal tunnel pressure than the effect from ulnar deviation.[6] The pressure in the carpal tunnel is influenced by the position of the wrist along with continuous movements of the fingers and wrist during typing tasks. When the wrist is held in a position of more then 30 of flexion or 15 degrees of extension, when typing, the pressure in the carpal tunnel exceeds 40 mm Hg.[1] At this pressure, there is both a decreased fluid flow in the area and impairment of median nerve function.[1] The pressure in the carpal tunnel also changes with the changes in ulnar deviation of the wrist. When the wrist is in 10 degrees ulnar deviation, the pressure in the carpal tunnel is at 15 to 25 mm Hg; where when the wrist is in 20 degrees ulnar deviation the pressure in the carpal tunnel increases to up to 40 mm Hg.[18]

Carpal tunnel syndrome can create dysfunction at the wrist and hand; this dysfunction can lead to increased direct and indirect expenses including days away from work.[3] The most recent estimates of prevalence of carpal tunnel, indicate that the disorder occurs in 346 people out of 100,000.[4] Since there is such a high prevalence in injuries associated with typing, companies are losing money to workers' compensation, and lost productivity. Between 1993 and 1994, 186,000 federal workers claimed mononeuritis. Ninety-three percent of these claims were due to CTS.[19] These employees lost an average of 25 days of work and $22-33,000 in medical costs and cost of lost days of work.[20] According to the Occupational Safety and Health Administration, carpal tunnel injuries are one of the leading causes of the most days away from work.[3] For many companies, a way to prevent the occurrence of CTS is to change to an alternative keyboard. By changing to an alternative keyboard, companies may be able to pay as little as $100 for the cost of the keyboard, rather then close to $30,000 due to CTS.[3]

Different Styles of Alternative Keyboards

Alternative keyboards are typically developed to bring the wrist and the forearm into a more neutral position, thereby decreasing WRMD's and increase worker comfort without negatively affecting productivity of a typist.[12,20] The styles of alternative keyboards include split-keyboards, angled-keyboards, separate-halves keyboards, and any combination of these.

The most commonly found alternative keyboard has a fixed slant-angle of 12.5 degree, slope-angle of 6 degrees, and a tilt angle of 7 degrees.[5] The slant-angle determines the amount of ulnar and radial deviation allowed by the keyboard. The

slope-angle determines the amount of flexion and extension allowed by the keyboard. The tilt-angle determines the amount of supination and pronation of the wrist. It is thought that by incorporating a slant-angle in the design of the keyboard there will be a reduction in wrist ulnar deviation. The slope-angle is thought to reduce the degree of wrist extension, and the tilt-angle will reduce forearm pronation.[5]

Split-keyboards use concept of a slant-angle to reduce ulnar deviation. The ulnar deviation for participants typing on a standard keyboard is typically at least 10 degrees.[6] Ulnar deviation has been shown to contribute to the fatigue of the forearm muscles, increase friction within the carpal tunnel, and increase pressure at the wrist joint.[15] With split-keyboards the slant angle can range from 0 to 15 degrees with a tilt-angle of 0 degrees.[5] When typing with the conventional 10-digit typing style, the use of a split-keyboard can decrease ulnar deviation of the wrist to within 5 degrees of a neutral position.[14] Marklin, Simoneau, and Monroe[6] found that if a split-keyboard has an opening angle of approximately 25 degrees (12.5 degrees slant angle), then wrist ulnar deviation is reduced to almost a neutral position in the radial/ulnar plane.

A group of authors suggested that typists are able to quickly adapt to the split-keyboard.[15] Originally, there was an initial drop in productivity and accuracy; however, it has been found that typists typically are able to return to baseline after a day or two.[15] The level of experience of the typist often influences the rate at which productivity and accuracy return to baseline. Experienced typists require a longer period of time to return to baseline due to the need to unlearn hand positions, movements, and key locations of the standard keyboard.[15] In contrast, novice typists are able to learn to type on a split-keyboard and standard keyboard at the same rate.[15]

The tented-keyboard is one version of the split-keyboard. This form of alternative keyboard helps to correct both ulnar deviation and pronation. The tented-keyboard places the typist wrists in a position in which the palms are angled vertically. The standard keyboard has the palms in a position in which they are facing downwards. This position had been found to increase stress and stretch the extensors and shorten the flexors of the wrist. The palms-down position has also been found to increase stress and shift the tendons in the carpal tunnel area potentially compressing the median nerve.[15] Unlike the typical split-keyboards, the tented-keyboard requires more time to return to the typist original productivity.[15]

The separate-halves keyboards are a type of a split-keyboard also used to increase ulnar deviation. Since the keyboard is in two separate-halves, the keyboard can be placed shoulder width apart thereby completely eliminating ulnar deviation.[5] The separate-halves also help to eliminate forearm pronation and shoulder abduction.[21] Instinctively, typing performance on separate-halves keyboards did not vary from that of a standard keyboard.[5] The participants typing did not change for both words typed per minute and accuracy. There were no changes noted as the separate-halves of the keyboard changed in distance from each other.[18]

Slant-angle keyboards position the wrist in a neutral position for ulnar deviation. A slant-angle of 12.5 degrees reduced ulnar deviation to 0 degrees; compared to the use of a standard keyboard where ulnar deviation was between 10 and 15 degrees. In one study, the mean ulnar deviation was reduced from 10.7 degrees on a standard keyboard to 2.5 degrees on an alternative keyboard for the left wrist and the right wrist was reduced from 13.3 degrees to 5.7 degrees of ulnar deviation.[5]

The keyboard slope is the angle of the plane of key to a horizontal.[22] Most standard keyboards have a positive slope of 6 to 7 degrees that requires the typist to extend the wrist approximately 20 degrees while typing.[9] Markin and Simoneau[5] compared 15 degrees, 7.5 degrees, 0 degrees, -7.5 degrees, and -15 degrees of sloped. In contrast, downward sloping of a keyboard reduced wrist extension and was shown not to reduce typing speed and accuracy.[22] Use of a keyboard with a downward slope-angle of -7.5 degrees places the wrist in a more neutral position, potentially decreasing carpal tunnel pressure.[5] The closer the wrist extension angles are to neutral, there is a decrease in the incidence of nerve conduction injuries affecting the wrist.[5] Use of a keyboard with a slope of -7.5 degrees slightly reduces electromyographic activity of the extensor carpi ulnaris, but at the same time it slightly increased ulnar deviation.[5]

Marklin and Simoneau[5] found that 10 digit touch typists indicated that the -15 degree sloped-keyboard to be the least comfortable, while a keyboard with a slope between -7.5 and 7.5 to be more comfortable. However, the authors recommended that keyboards should not be sloped greater than 7.5 degrees due to the relationship between this elevation and musculoskeletal disorders.

In another study, Simoneau, Marklin, and Berman[22] analyzed the effect of computer keyboard slope on wrist position and forearm electromyography of typists. Sixteen experienced typists without musculoskeletal disorders participated in this study. The standard keyboard was sloped at angles of 7.5 degrees, 0 degrees, -7.5 degrees, and -15 degrees.[22] Extension and ulnar deviation were measured with electrogoniometers. Electrodes were placed on the extensor carpi ulnaris, flexor carpi ulnaris, and flexor carpi

radialis to measure electromyographic activity during typing at the various keyboard slope angles.

The authors found that when changing keyboard slope from 7.5 degrees to 5 degrees wrist extension angle decreased from 12 degrees to 3 degrees of flexion.[22] Ulnar deviation increased 3 to 5 degrees from a keyboard slope angle of 7.5 degrees to -15 degrees.[22] The degree of muscle activation and contraction of the extensor carpi ulnaris decreased as the keyboard slope decreased. As the keyboard slope changed from 7.5 to -15 degrees, the muscle contraction of the extensor carpi ulnaris decreased from 13.5% to 11.5% of a maximum voluntary contraction.[22]

Previous researchers have indicated that 5 different sloped keyboards had an effect on wrist extension.[9] The etiology of WRMD is associated with deviated wrist postures in the flexion/extension plane.[9] During the study conducted by Simoneau and Marklin,[9] 30 participants typed on a standard keyboard whose slope was adjusted to 15 degrees, 7.5 degrees, 0 degrees, -7.5 degrees, and -15 degrees. Wrist extension changed significantly for all 5 slope configurations. Wrist extension decreased approximately 12 degrees as keyboard slope-angle moved from 15 degrees to -15 degrees. Simoneau and Marklin reported there was an increase in ulnar deviation with negative sloped-keyboards. They also concluded that the mean ulnar angle of the wrists varied significantly between the keyboard slopes. Even though there was a decrease in wrist extension the resulting increase in ulnar deviation may diminish the benefits.

Benefits of Alternative Keyboards

Alternative keyboards offer many benefits to people who type for extended periods of time. People who type for extended periods of time are at risk for developing

musculoskeletal injuries. Alternative keyboards adjust the angle at which the wrist is held, thus reducing the risk of developing of these injuries. Besides reducing the risk of developing musculoskeletal injuries, alternative keyboards are shown to increase productivity and comfort of typists.[23]

One benefit associated with alternative keyboards is the decrease in ulnar deviation. Marklin[18] conducted a study that looked at the affects of split-angled keyboards on ulnar deviation. In this study, there were 4 keyboards compared, 1 convention keyboard, and 3 alternative configurations consisting of: (1) centers of keyboards halves separated at 20 cm distance, (2) keyboard halves separated at half the distance of the subject's shoulder width, and (3) keyboard halves separated to the distance of the subject's shoulder width. The mean angular data from the 3 alternative keyboards were less than the mean ulnar deviation from typing on a standard keyboard. No variation for wrist ulnar deviation among the 3 alternative split-keyboards was found. The author concluded that alternative keyboards are beneficial in promoting a neutral wrist alignment and in theory decrease exposure to WRMDs.[18]

In the review of the literature, Simoneau and Marklin documented that productivity or accuracy was not compromised by switching to an alternative keyboard.[9] The authors studied 5 different keyboard slopes and the impact the slopes had on typing speed.[9] The words per minute (wpm) ranged from 54.7 to 56.9 words per minute and no difference for typing speed was noted with the amplitude of varying keyboard slopes ($p=.17$).[9] Accuracy among the 5 keyboard slopes was not significantly different ($p=.29$). Simoneau and Marklin[9] concluded that experienced typists were able to quickly adapt to the alternative keyboard slope-angles and height within 6 minutes of practice. The mean

typing speeds were 54-58 words per minute with over 99% accuracy. Marklin performed another study and compared productivity of split-keyboards and a standard keyboard. There was no significant difference with different styles of keyboards.[18] The mean typing speed ranged from 48.9 wpm for the split-keyboard, at shoulder width apart, to 52.5 wpm for the standard keyboard.[18]

Marklin[17] found a difference in the psychophysical assessment of discomfort for the neck, dependent on the keyboard used. The mean Borg score of discomfort for the neck was 0.92 for the standard keyboard and 0.31-0.62 for the alternative split keyboards, allowing the authors to conclude that the subjects favored the alternative keyboard.

Keller, Fleischer, and Strasser[23] also compared standard keyboards to ergonomically designed keyboards using subjective measures. Workstations, hands, forearms, upper arms, and shoulder positions, as well as overall impressions of the keyboards were subjectively evaluated using a 4-step bipolar scale. The 4-step bipolar scale ranged from -4 to +4. A score of -4 was coded as extremely unfavorable and a score of +4 was coded as extremely favorable.[23] Questionnaires were administered before and after the tests to measure the parameters of posture, comfort, and working conditions; as well as design and functional parameters of the ergonomic keyboard.[12] The working posture was reported to be more favorable for the ergonomically designed keyboard. The overall impression of the keyboard and comfort were also rated significantly higher for the ergonomic keyboard. The subjects responded that they believed that they exerted less effort on the ergonomically designed keyboard.[23] The authors concluded that by using the ergonomically designed keyboard or the split-keyboard, the hands were in a more neutral position; therefore, reducing the risk of injury.

Methods to Measure Productivity

With the increased number of occupational injuries associated with carpal tunnel syndrome and other distal upper extremity injuries, companies are potentially losing money due to workers days away from work and lost productivity. There are many programs and machines to measure workers' productivity. Accuracy and words per minute are commonly used to determine whether or not typing productivity has been compromised.

Typists may believe that their productivity will decrease with the application of ergonomic keyboard. There are many different ways to measure productivity of typists on keyboards. The methods available include means of measuring stress and force placed on a typist's hands, along with the accuracy and word count of the typing content. These methods include 3-D motion analysis systems, computer programs, and subjective observations.

One method of measurement is the Typing Tutor 6.0* software. This method allows the typists to become familiar with the keyboard through typing drills. Once a participant is familiarized with the keyboard the Typing Tutor can record typing speed (words per minute), accuracy, the total characters typed, and the total number of errors for a document.[6] In the study conducted by Marklin, Simnoneau, and Monroe[6], validity and reliability were not documented for this product.

Video recording can also be used to document the participants' positioning and posture of the participant. The video recording method allows researchers to document the angle of the wrist while typing along with body posture. The video recording method

*Kriya Systems, Inc., Sterling, VA

allows the researcher to determine if the posture of the participant impacts the stress placed on the shoulder, elbow and wrist when typing. Video recording helps determine whether posture influences accuracy and productivity of typists.[11] Depending upon the desired detail of the research, accuracy and positioning is often compromised. This compromise occurs due to the increased number of sensors and accessories that may restrict and inhibit the performance of the typist. [10] By restricting and inhibiting the performance of the typists validity and reliability of this product was not assessed.

Another method that can be used to monitor typing activity is the KBlog.* The KBlog was designed to monitor typing activity without interfering with computer activity. Once the KBlog is installed into a computer, it continuously records typing activity. The KBlog records the typing motion along with how long a key is held and the typing frequency. Given that the KBlog records the typing motion, the data can be used to identify the length of time a key is held, the frequency of typing and the frequency of taking breaks.[10] According to a study conducted by Chang et al,[10] the KBlog is accurate for recording the amount of time a key is held and then released as long as the computer is running under normal operating conditions. When compared to the video analysis instrument it was determined to be more accurate and reliable, and cost less.
Formulas can be used instead of computerized programs. In a study conducted by Zecevic and Miller, a formula was used to calculate productivity of their participants.

$$P = ((C - 2E)/5) * (60/T).^{24}$$

In this formula, P represents productivity, C represents characters typed, E is the number

*Visual Basic Microsoft 2000, USA

of errors, and T is the time period in seconds. In this study, the validity and reliability was not documented for this formula.

Previous researchers have used several indirect measures of productivity such as participant comfort. The measurement of participant comfort can be recorded with administration and completion of a questionnaire. In a study conducted by Keller, a Likert scale was used to evaluate the participants' opinion on comfort, posture, and overall impression of the keyboard.[23] In this study, validity and reliability was not documented for this product.

The Personal Computer Keyboarding Style (PeCKS), was an instrument that was recently developed to record static body position, wrist hand and finger position and tension and force placed on the upper extremities.[25] The PeCKS instrument allows evaluation of the risk factors of individual keyboards could place on typists. The PeCKS can be used to assess a typist's environments and to develop interventions to reduce potential risky typing styles.[25] By understanding the method in which a musculoskeletal injury occurs, physicians and therapists will be able to better assess and treat patients with injuries due to typing on keyboards. The validation of the development of this instrument is based upon scientific literature and confirmed by experts in the field. Until more research is completed reliability and validity will not be assessed by the developers. To establish reliability, developers will be comparing analysis of video recordings by the PeCKS and the Intraclass Correlation Coefficients. Once reliability has been established, developers plan to assess validity of the instrument by further comparing observational measures using the PeCKS with kinematic measures obtained by using a motion capture

system. Once adequate validity and reliability of the product has been established this instrument has the potential to be a useful tool for both clinical and research use.[25]

Time Period Required to Return to Baseline Typing

Conflicting information is available about the period of time it takes a typist to return to baseline productivity after changing to an alternate keyboard. One study has indicated that within 6 minutes of using an alternative keyboard, experienced typists are able to return to the same typing speed as on a standard keyboard.[5] In different study, there is only a decline of 4 words per minute when changing to either a fixed slant-angle or an adjustable slant-angle keyboard from a standard keyboard. This decline was present with only a few hours of practice.[5]

Marklin, Simoneau, and Monroe[6] concluded that after 20 hours of practice on an alternative split-keyboard typist had a 5 percent decline in typing speed. In their study, the participants had a mean average of 14.4 years experience, and were divided into 3 groups each with a different alternative keyboard. There was no statistical significance in productivity after switching to any of the 3 forms of keyboards (split adjustable-angle keyboard, split fixed-angle keyboard, and standard keyboard).

However, in a study conducted by Smith,[7] it was documented that other investigators have found that adjustment to alternative keyboards requires at least 2 hours of typing. In contrast, a study by Swanson et al[8] documented that typists who used a vertically inclined keyboard required 5 hours of practice rather then 2 hours to return to original productivity. After reviewing the conflicting results of other researchers, Marklin, Simoneau, and Monroe[6] suggested that a minimum of 10 hours of practice is needed to achieve normal typing speed to overcome the unfamiliarly of the alternative keyboards.

Summary

The problem with typing on standard keyboards is that the hands and wrists are forced into an non-natural, tense position which can lead to repetitive stress injuries.[3] The most common form of repetitive stress injury associated with typing is carpal tunnel syndrome. Businesses may find that the initial costs in pre-empting injuries are high; however, by investing in ergonomically designed keyboards may bring savings in worker's compensation costs.[3]

There are a variety of ergonomically or alternative designed keyboards such as split, slant, tilt, and sloped. Each of the alternative designs help to reduce extension, ulnar deviation, and pronation which places the wrist in a more neutral position.[5] Even though there are physical benefits to alternative keyboards, there is conflicting research on whether alternative keyboards substantially affect productivity and accuracy. [5,6]

APPENDIX B

Demographic Questionnaire

Please answer the following questions:

1. Age: _____
2. Number of hours typed per day:

   Less then 2 hours 2-4 hours

   Greater then 4 hours
3. Number of years experience: _____
4. Do you have a current musculoskeletal injury related to typing:

   Carpal Tunnel Tendinitis Other_____
5. Previous musculoskeletal injury(s) related to typing:

   Carpal Tunnel Tendinitis Other_____
6. What is your highest level of Education:

   High School Some College Associates Degree

   Bachelor Degree Master's Degree PhD
7. Have you ever used an alternative keyboard?Yes No

   If yes… Less then 3 weeks 1-3 months

   More then 3 months
8. What type of keyboard do you primary type on?

   Flat Keyboard (standard) Laptop

   Split-Angled Keyboard

APPENDIX C

Survey

Please answer the following questions:

1. After using the alternative keyboard, which keyboard do you prefer?

   Alternative Standard

2. Why? _____

   _____

3. Which keyboard were you more comfortable using?

   Standard Alternative

4. Which keyboard did you feel that you exerted more force on?

   Standard Alternative

5. Any other comments about your use of the alternative keyboard?

   _____

   _____

   _____

   _____

APPENDIX D

INFORMED CONSENT FORM

CONSENT TO PARTICIPATE VOLUNTARILY IN A RESEARCH INVESTIGATION

DEPARTMENT OF PHYSICAL THERAPY
SPRINGFIELD COLLEGE
SPRINGFIELD, MA 01109

_____ _____
Responsible Faculty Member **Investigator's Name**

_____ _____
Subject's Name **Date**

PROJECT TITLE:

You are being asked to participate in a research investigation as described in this form below. All such investigational projects carried out within this department are governed by the regulations of both the Federal Government and Springfield College. These regulations require that the investigator(s) obtain from you a signed agreement (consent) to participate in this project.

The investigator will explain to you in detail the purpose of the project, the procedures and/or drugs to be used, and the potential benefits and foreseeable risks of participation. You may ask the investigator any questions you may have to help you understand the project and you may expect to receive satisfactory answers of questions. A basic explanation of the project is written below.

If, after this discussion, you decide to agree to participate in the project, please sign this form on the line indicated below in the presence of a witness and the investigator.

I. The purpose of this research project is to determine whether typists are able to reach original productivity and accuracy when changing from a standard keyboard to a split keyboard.

The approximate number of subjects involved in this project is 30.

Your participation in this project will entail approximately 1 ½ hours.

The Procedures to be used include:

1. Each participant will complete a demographic questionnaire.

2. Once eligibility has been established, each participant will sign a written consent form (this document).
3. Testing sessions will be conducted in an isolated room away from distractions.
4. The workstation will be set up ergonomically for each individual participant.
5. Three baseline typing measurements of words per minute and accuracy will be taken on a standard keyboard for 5 minutes each, with a 3 minute break between each trial.
6. After a 3 minute break, a baseline measurement will then be taken on an alternative keyboard for 5 minutes.
7. Data collection of words per minute and accuracy for the alternative keyboard will occur at 10 minute intervals for 60 minutes. During the 10 minute interval, five minutes of typing from the standardized document will be collected.
8. After completion of the data collection, each participant will complete the survey regarding their opinion of the keyboards used.

II. The risks and the safeguards taken to minimize the risks are as follows:
    1. Typing for 60 minutes could increase the risk of developing a musculoskeletal repetition injury.
    2. Participants may experience minor discomfort due to different keyboard angles.
    3. Task doesn't exceed normal daily work experience for participants.

III. The information obtained about you will be kept in confidence, although you are free to release it to your own physician. The information may be used for statistical or scientific purposes without identifying you as an individual.

Any significant new findings will be provided to you during the course of the study.

You are free to withdraw from this project at any time without penalty or lose of benefits to which you would otherwise be entitled.

Should an unforeseen physical injury occur, appropriate first aid will be provided, but no financial compensation will be given. Further information can be obtained from the Office of Graduate Studies of Springfield College concerning pertinent questions about the research and an explanation of your rights as a research subject. The Graduate Office serves as the official contact office in the event of research related injury to you (413-748-3125).

I CERTIFY THAT I HAVE READ AND FULLY UNDERSTAND THE ABOVE PROJECT. MY QUESTIONS HAVE BEEN ANSWERED TO MY SATISFACTION BY THE INVESTIGATOR. I WILLINGLY CONSENT TO PARTICIPATE.

Signature of Witness	**Signature of Subject or Guardian**
Date	**Signature of Investigator**

IF SIGNED BY AGENT OTHER THAN SUBJECT, PLEASE EXPLAIN BELOW
__ MOTHER ___ FATHER ___ LEGAL GUARDIAN

APPENDIX E

Timeline for Data Collection.

	Baseline Measurements Typing on a Standard Keyboard					
	Trial 1		Trial 2		Trial 3	
Time (min)	**5** type and record	**3** rest	**5** type and record	**3** rest	**5** type and record	**3** rest

	Measurements Typing on an Alternative Keyboard (65 minutes)												
Time (min)	**5** type and record (baseline)	**5** type and record	**5** type and record	**5** type and record	**5** type and record	**5** type and record	**5** type and record	**5** type and record	**5** type and record	**5** type and record	**5** type and record	**5** type and record	**5** type and record